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SCIENCE PROGRESS

THE FLOOR OF THE OCEAN

By P. G. H. BOSWELL, D.Sc., F.R.S.

Professor of Geology in the University of London, Imperial College of Science and Technology

ALTHOUGH Kipling's village of Huckley, led by 'Dal Benzaguer herself, may have voted that the Earth *Is* Flat, it is undoubtedly a fact that general opinion, outside perhaps Zion City, Illinois, holds to the view that it is a globe. But undue satisfaction in regard to our knowledge of this globe is hardly warranted when we remember that three-fifths of its surface is almost unknown to us. For this large proportion of the earth's crust (the lithosphere) is covered by the oceanic envelope called the hydrosphere. The margins of the seas have fluctuated since the earliest geological times and they fluctuate to-day; as the sonneteer observed:

When I have seen the hungry ocean gain
Advantage on the kingdom of the shore,
And the firm soil win of the watery main
Increasing store with loss, and loss with store,

And notwithstanding its imperfections, the geological record has been fairly plainly written by these marginal fluctuations, but what lies beneath the depth of the ocean, being invisible and only slightly accessible, is still but little known. Yet when we are asked what contribution the progress of science is making to deep-sea lore, we can answer that during recent years significant advances have been made in our knowledge both of the form of the ocean-floor and the deposits ~~on~~ over it.

It is not the purpose of the present essay to consider the origin or the age of the great oceanic basins—whether ~~and~~ original planetary features,

by the ~~continental~~ ~~the~~ continents. These questions have discussed almost *ad nauseam* during the past two decades, suffice it to say that the consensus of geological opinion does not

favour the Wegener hypothesis of continental drift, although admitting the possibility that such drift may occur in certain parts of the crust on a relatively small scale. This matter concerns us here only in so far as the form and covering of the ocean-floors may throw light on the controversy.

The variation in depth of the oceans over the surface of the globe is familiar to all. In their main outline, the bathymetrical contours have long since been plotted, and the work of recent deep-sea exploration has only necessitated modification in detail of such contours. The broad distribution of deep-sea deposits—the organic oozes and red clay—in relation to depth is also a matter of general knowledge. The character of these deposits and the areas and depths of the floors where they occur was first made known from the classical investigations of the *Challenger* expedition in 1880, although earlier expeditions had foreshadowed some of the results. Since then numerous scientific explorations have been made, and have duly been referred to in textbooks of oceanography.

With certain exceptions, the types of deposits found on the ocean-floor are related to the depth, the distribution of the various types corresponding with different submarine levels. A clear picture of the respective areas in relation to the heights or depths is furnished by what is known as the hypsographical curve of the earth's surface. From this diagram, in which areas are plotted as abscissæ and heights as ordinates, it becomes evident that two levels are most widespread. The first is a land level consisting of the greater part of the continents (all but about 9 per cent., which constitute the "mountainous" areas) together with a continental shelf that is submerged beneath the sea to an eventual depth of about 100 fathoms (nearly 200 metres) at its margin. The second is the deep-sea level, which includes most of the ocean-floor; this, if regarded as lying between 1400 and 2800 fathoms ($2\frac{1}{2}$ and 5 kilometres) in depth, occupies about two-fifths of the earth's surface. The ill-defined stage connecting these levels, that is, the continental slope, is of small extent, possibly 8 per cent. of the earth's surface, and the deeps or sinks in the ocean-floor lying below 3000 fathoms in depth ($5\frac{1}{2}$ kilometres) constitute only about 4 per cent. of the surface, although this proportion may prove to be slightly greater when more records of depths are obtained. The deep-sea area, including the deeps, thus comprises some 115 million square miles (295 square kilometres), or more than half the earth's surface; the character of its surface and covering would therefore appear to merit greater attention than they have hitherto been given, especi-

ally when we recall the vast literature concerned with the geology of the continental areas of the globe.

Successive expeditions have added considerably to the number of sounding stations originally established by the *Challenger*, and we now realise that the ocean floor has topographical irregularities no less impressive than those of the continents. Moreover, the employment during recent years of echo-sounding methods, so economical of time and labour, has revealed interesting features such as submarine canyons, deep hollows and scarp-like elevations. Now that some hundred canyons have been located, Professor R. A. Daly has recently done good service by assembling the evidence relating to them. He notes that several occur along the continental shelf between the latitudes of Cape Cod and Cape Hatteras, including the classic "Hudson River Canyon" off New York City. Thirty examples have been found along Georges Bank off the New England coast and an even greater number between the northern end of Vancouver Island and southern California. Others have been determined off the Hawaiian Islands, in the northern and western parts of the Gulf of Mexico, off the western coast of Mexico, the Bahama Bank, the coasts of Brazil and Ecuador, the eastern coast of Korea, both eastern and western coasts of Japan, eastern and southern coasts of Formosa, off the mouths of the Ganges and Indus and the coast of Ceylon. Around the African continent, they have been proved to occur south of Zanzibar, off the south coast, opposite the mouths of the Congo, Ogowe and Niger, and off the Gold Coast and Cape Verde. In Europe, they have been located in the region beyond the coasts of Portugal, France and the British Isles. Thus their distribution is world-wide. Many extend as cuts through the continental shelf and reach a depth of at least 1000 fathoms. Although some have no direct topographical connection with great rivers (for example, those closely spaced on Georges Bank), most are on the axial lines of such, notwithstanding the fact that delta-building is in progress. In relation to the continental shelf, they usually run straight down in the direction of slope—as though formed by rivers "consequent" on the shelf, their longitudinal gradients being from 1 in 100 to 1 in 10. Some are shallow, that is, not deeper than 50 fathoms (100 m.) and confined to the area of the shelf, but many show depths reaching from 500 to 1600 fathoms. Their walls are steep, the gradient being apparently from 1 in 3 to 1 in 1, and from the walls of those off California masses of fossiliferous Upper Cretaceous and late Tertiary clays have been dredged.

The mode of origin of these canyons has long been a problem—

indeed, ever since the time when Buchanan attributed the classic example found off the mouth of the Congo to submarine river erosion. Some examples have probably arisen in this way, but it seems unlikely that submarine rivers can cut to great depths in relatively deep and quiet oceanic waters, even if we grant Daly's postulate, that such streams, being laden with mud, have increased erosive powers. Other canyons are probably tectonic; that is, are due to down-folding or faulting of the earth's crust under the sea. But the problem in general remains.

Ridges, scarps or deeps on the sea-floor have been recorded from time to time, but latterly more precise information has been furnished by the work of the Dutch *Snellius* expedition and our own *John Murray* expedition in the Red Sea, Arabian Sea and Indian Ocean. As the investigators on the *Snellius* expedition emphasised, the possibility of a submarine fault assuming gigantic proportions is not in accord with Wegener's theory of a plastic substratum which is necessary for the drift of continental masses. Thanks to Dr. Vening Meinesz's investigations of the value of gravity at sea, made by pendulum observations in submerged submarines, it has become possible to relate the deeps, which are usually long and narrow depressions of the sea-floor, to long and narrow belts of strong negative anomalies of gravity. Thus there is more than a suggestion that such deeps are of tectonic origin, and consequently due to down-folding or fracturing of the crust. As has long been realised, the best-known deeps, such as those south of the Java-Timor arc and north-east of the Antillean arc, are situated in the neighbourhood of land-masses where earth-building movements have recently been active. The same is probably true of the Nero Trough of the Marianas, the Atacama Deep and the South Sandwich Islands Deep.

We pass to the consideration of the deposits at present being laid down on this submarine surface of varied relief. We have as yet no evidence of any relationship between the canyons and deeps and the type of sediment deposited, but apart from these, it is generally true to say that the deep-sea sediments vary in character according to the depths of water in which they have accumulated. Several expeditions, notably the *Meteor*, the *Carnegie* and the *Discovery II*, have recently provided additional information about such deposits, but it is a tribute to the work of the *Challenger* expedition that the classification introduced half a century ago still stands. The various expeditions of the research ship *Discovery II*, begun in 1925, are still in progress. Organised by the Colonial Office with the view of acquiring knowledge of the impor-

tant economic problem of the feeding and breeding of whales in the South Seas, the personnel of the expeditions lost no opportunity of making scientific observations relating to the depth, salinity and temperature of ocean waters, to marine life of all kinds, and to the character of sea-bottom deposits. Valuable results are gradually being published in a series of volumes, but inasmuch as many of the specimens must be examined by busy specialists, much information is still awaited, including the detailed descriptions of the floor-deposits. But already results of surprising interest have been announced. The classification of the deep-sea deposits introduced by Sir John Murray of the *Challenger* expedition requires modification only in detail: it may now be summarised thus:

Shallow-water deposits (between L.W. and 100 f.)	<div style="display: inline-block; vertical-align: middle;"> { Gravels Sands Muds </div>	} Terrigenous deposits (containing detrital material).
	<div style="display: inline-block; vertical-align: middle;"> { Glauconitic mud Diatomaceous mud </div>	
Deep-Sea deposits (below 100 f.)	<div style="display: inline-block; vertical-align: middle;"> { " ooze Globigerina " } Pelagic deposits. Radiolarian " Red Clay </div>	

Except for the red clay, the pelagic deposits are almost entirely organic, and they fall into two groups consisting respectively of predominant calcium carbonate or amorphous silica. The calcareous materials include immense quantities of coccolithophores, which are calcareous algæ, the well-known coccoliths being the separated plates of the skeletons; foraminifera, chiefly *Globigerina* and allied forms; and pteropods. The work of the German *Meteor* expedition demonstrated that in the Atlantic the coccolithophores are of wide distribution in the ocean, but the *Globigerinæ* lived almost exclusively in temperate or warm water. The solubility of the skeletons of these organisms, which are composed of calcium carbonate, increases with pressure and fall of temperature, that is, with increased depth of water. The siliceous organisms consist of four groups: diatoms, silico-flagellates, radiolaria, and siliceous sponges. The diatom frustules are exceedingly small and enter into deep-sea deposits only where other remains, such as calcareous skeletons, are dissolved away, and where mineral material derived from erosion of the land is slight—as for example in Arctic and Antarctic regions. The occurrence of radiolaria in sea-water is similar to that of other plankton, but the main distribution of radiolarian ooze in the Pacific and Indian Oceans lies in the deeper regions, where the depth and low temperature have assisted in the solution of calcareous remains as they settle down. Recently Dr. E. Neaveyerson has noted the presence of radiolarian ooze among

the samples collected by *Discovery II*, from the South Atlantic, a first record. Of these deposits, the globigerina ooze and the diatomaceous ooze together occupy a large proportion of the ocean floor, the former fifty million square miles, extending down to a depth of 2500 fathoms, and the latter eleven million square miles, principally at a less depth and in the colder regions. But there remains a third deposit of even greater extent (fifty-two million square miles)—the red clay, which is confined to the deepest regions, like the radiolarian ooze. It is found mainly in the Atlantic Ocean, though why it should occur there, and the other very deep-water deposit chiefly in the Pacific and Indian Oceans, is at present not clear. The red clay is entirely mineral in character, consisting of particles of 2 microns (.002 mm.) diameter, together with finer clay material. It has been regarded as in part the insoluble residue of the skeletons of organisms, left after solution of calcium carbonate, silica and other constituents by subsidence through the great depths. But its mineral constitution does not lend support to this view, nor is it borne out by the characters of the insoluble residues shown by chemical analyses of skeletons of marine animals. More probably it results from the slow accumulation of fine volcanic dust, which is blown over the ocean for great distances, and from the decomposition of volcanic products such as ash, pumice and basalt, which have fallen into ocean waters. In addition, however, to minerals such as feldspar and augite (and in the clayey portion, montmorillonite) which could be derived in this way, there are many tiny grains of quartz, a mineral unlikely to occur except rarely in products of oceanic volcanoes. The presence of these makes it seem likely that wind-blown material other than volcanic dust must reach the depths. Indeed, Stefansson observed that off-shore winds carried sand and even gravel far out on to off-shore ice, and others have recorded dust-falls derived from the Saharan region, at a distance of 1700 miles west of the African coast. In the great 1912 eruption of Katmai in Alaska, a thickness of 6 mm. of volcanic dust was deposited at 220 miles distance; also, the effects of dust from Krakatoa carried three times round the earth in 1883 are still remembered. Further, it has been observed that in samples from both the Narrow Seas and the South Atlantic relatively coarse grains of quartz are buoyed up by filamentous masses of flocculent protoplasmic or other organic material and can travel thus for long distances in the sea.

Little work has been done on the constitution of the clayey fractions of pelagic deposits, but preliminary X-ray investigations by Professor C. W. Correns of Rostock showed that a sample

of red clay collected by the *Meteor* is composed of kaolinite, calcite and muscovite mica. There is here an extensive field for investigation.

When we recall how these pelagic deposits have arisen, we realize that the rate of accumulation must be extremely slow. Schott has estimated that in 1000 years a thickness of 17·8 mm. of blue mud, 12 mm. of globigerina ooze, and less than 8·6 mm. of red clay would be laid down. No surprise need be felt therefore at the oft-quoted statement that teeth of sharks dredged from the ocean floor, of species now extinct, have been found to be covered with only a film of deposit. On the other hand, there is the surprising record of some inch or two of globigerina ooze found covering the Atlantic cable when it was brought to the surface for repair. An inch of deposit in less than a century is almost incredible ; and we are obliged to consider the possibility of the cable having sunk in the ooze.

For many years before the *Challenger* expedition the pioneer methods of bottom-sampling by means of lead-sinkers were followed, but subsequent improvements in technique led to the recovery of samples in valved tubes, that is, small borehole samples were obtained. Even then, only the surface layer of the sea-bottom was penetrated. Efforts have therefore been directed to obtaining longer and still longer cores from the ocean floor ; the *Meteor* obtained cores 1 metre in length, and the *Snellius* afterwards brought up cores of a length of 2 metres or more. The possibility of obtaining a stratigraphical succession of floor deposits is fascinating to geologists, because clues to changing conditions of fauna, climate and depth during geological ages may thus be yielded.

One of our own most versatile investigators, the late Professor John Joly, of Dublin, devised a form of deep-sea apparatus for obtaining core-samples. More recently, Dr. C. S. Piggot, recognising the necessity of improving on the results obtained by the ill-fated American research ship *Carnegie*, has devised a new type of apparatus, by which the contact of the sampler with the sea-floor actuates the trigger of a firing mechanism and so forces the tube down farther than the few feet to which it would be driven by the momentum of the falling weight. Experimental work indicates that cores from 4 feet to 8 feet 8 inches in length can be obtained from depths varying from 200 to 1250 fathoms.

Already, however, the older method of coring has shown the presence of different deep-sea deposits in superposition ; of globigerina ooze resting on blue mud, and of red clay overlying globigerina

ooze, as noted by Correns in his accounts of the *Meteor* samples. Now W. Schott's statistical studies of the fauna of South Atlantic waters indicate that at a depth of about 25 cm. in the ooze, warm-water foraminifera such as *Globorotalia menardii* cease to occur, while *Globigerina bulloides* and *G. inflata* which favour cooler but still temperate waters increase in quantity. This kind of faunal variation, already conjectured by Philippi, the geologist to the *Gauss* expedition, suggests that the deep-sea deposits can furnish evidence of a climatic change. That the variation is not due to the drifting currents is shown by the similarity of the present distribution in the Middle and South Atlantic of *G. bulloides* in oceanic waters and in the superficial floor-deposits. It is possible that the underlying deposits from which *Globorotalia menardii* is absent were laid down during a recent cold period—perhaps the last phase of the Ice Age. Further, if we assume that the area occupied by the limeless red clay is extensive because cold deep waters are strongly solvent on calcareous skeletons, the fact that red clay overlies a globigerina ooze, which in turn overlies beds with warm-water forms, suggests that a warm period preceded the cold one. At the moment such conclusions may be speculative, but they point the way to promising investigations.

Many years ago it was deemed probable that the deep-water sediments were more highly radio-active than terrigenous deposits, although there was some doubt regarding the early determinations of radium-contents by Joly and by Pettersson in the samples they examined, collected by the *Challenger*, *Albatross*, and *Princess Alice II*. More modern methods adopted by C. S. Piggot in the analysis of samples of globigerina ooze, red clay and blue mud collected by the *Carnegie* have shown that the earlier conclusions were well-founded. Only 28 sediments, obtained from stations scattered throughout the Atlantic Ocean, were tested by Piggot, —a small enough number to represent such a vast area. With a few exceptions the specimens proved to have an extraordinarily high concentration of radium as compared with that of continental rocks, such as ancient sediments and granite, and even more so as compared with basalt. The general average of Piggot's analyses shows $6.52 \text{ g.} \times 10^{-12}$ radium per gram of sediment; for comparison, an average for granite might be assessed at 2.5×10^{-12} and for basalt at 0.8×10^{-12} , although many granites give a figure more like that of basalt. Exceptionally high contents noted by Piggot in sediments from the deepest parts of the oceans, such as red clay, reached 21.40×10^{-12} and 16.72×10^{-12} .

What is the source of this radium and what is the geophysical

significance of the relatively high content of the coating of the ocean-floor? To elucidate the first problem, Piggot turned to minerals believed to be in process of formation in the depths, and chose some of the manganese nodules which reveal growth banding with trapped clay layers between the coats of manganese oxide. Uranium was found to be fairly evenly distributed throughout a nodule, and the radium-content was high, although it varied in the different constituents of the nodules. The problem is therefore concerned rather with the parent uranium than with radium itself, and it has been suggested that the concentration is brought about by the numerous minute living organisms in the sea which extract, more or less selectively, the salts of uranium and radium from the sea-water, and incorporate them in their skeletons. When they die their remains take the radio-active material to the bottom with them. Piggot disagrees with this view, and also with that of Pettersson, who ascribed the high concentration to submarine vulcanism. The uranium in sea-water must come ultimately from igneous rocks which are broken down on land. It is of course in solution in sea-water, and if we are to judge by the radium-content, it is in much the same proportions there as in ordinary rocks. Near the shore the radium-content of the sediments only approximates to that of the ordinary rocks of the continent; thus the enrichment in depth cannot be explained by detrital accumulation. Moreover, as stated above, red clays (which are the richest of the deposits) are believed to accumulate exceedingly slowly from decomposition of volcanic material, diluted perhaps by residues from skeletons of organisms and rare wind-borne detritus. Piggot suggests that although some uranium may be brought down by the settling of skeletal remains and volcanic dust, the greater proportion comes out as a result of oxidation at depth, for the oxygen-concentration in sea-water increases, according to the *Carnegie's* records, with depth below 1000 fathoms. On the other hand, in shallow water or near to continents sufficient organic matter is present to maintain the reducing conditions, which tend to keep the uranium in solution. The environment at the bottom of the ocean being of an oxidising rather than reducing nature, organic material disappears, and the water must be almost at saturation with respect to oxides of uranium. Thus there is a tendency for them to separate out like the oxides of iron and manganese.

The data obtained by the *Carnegie* regarding this increase in oxygen concentration throws light on various other phenomena and even on the colour and composition of the deepest deposit—

red clay itself, but they raise a difficulty when we try to explain the fresh and unoxidised condition of many of the minerals in deep-sea deposits. A considerable number of these minerals, as well as the fragments of volcanic glass associated with them, are of a type that is far from resistant to the effects of weathering, such as oxidation and hydration, on land. Reference is made below to the volcanic origin of most of such minerals. Well-known examples like olivine, augite, hypersthene, and biotite mica, are found in deep-sea sediments in a fresh unaltered state, often with crystal faces still sharply defined. Submarine "weathering," to use a contradictory term, cannot therefore proceed on the same lines as the corresponding process on the continents. If the conditions in deep waters are oxidising, we may ask what it is that inhibits the process analogous to weathering (the "halmyrolysis" of some authors). We can only suggest possible explanations of this "stabilised" condition of affairs; for example, that (a) the waters are charged to saturation with carbon dioxide, (b) they are kept at an approximately low and relatively constant temperature, (c) the pressure is great, often exceeding 500 atmospheres, or even (d) light is absent.

From the foregoing, it will have become evident that there are three possible sources for the mineral material of deep-sea sediments deposited beyond the reach of river-borne detritus, namely, (a) the products of volcanic eruptions, either submarine or wind-borne from terrestrial outbursts, (b) non-volcanic dust carried by wind from distant lands, and (c) detritus dropped from melting icebergs at extreme distances from their source. A little further consideration may now be given to the effect of volcanic action.

Our attempts to penetrate the superficial layer of the ocean-floor are necessarily very limited, and the likelihood of establishing the nature of the foundation rock of the crust is remote. But indirect evidence is afforded by the submarine volcanoes which are numerous and widespread in the oceanic areas. Many are of immense size and some rise, like Mauna Loa in the Hawaiian Islands, from the ocean depths to heights of 13,600 feet above sea-level. Indeed, most of the islands which lie far from continental shores are composed exclusively of rocks which have cooled from the molten state, and mostly of rocks of volcanic origin as distinct from deep-seated origin, i.e. those that have solidified in the depths of the earth's crust. The rock basalt, familiar to all in the Giant's Causeway and the Hebrides, is of commonest occurrence in oceanic islands, and the broad similarity of the chemical composition of

specimens from widely separated island localities points to derivation from a common sub-crustal region or shell. In some islands there is a sorting-out of mineral (*i.e.* chemical) constituents, known as differentiation, which leads to the formation by crystallisation of various rock-types, but these are rarities from the standpoint of total bulk.

It is common knowledge that when lavas are emitted from volcanoes on dry land, they not infrequently (like Vesuvius, for example) float up fragments of the "country-rock" more or less baked and sometimes in part assimilated at their margins. The "intrusive" representatives of the lava, that is, the feeders which become consolidated before they reach the surface, contain many more such "xenoliths." In a country where the crustal rocks are concealed by the volcanic pile, useful information is thus afforded of the nature of the superficial crust. But in oceanic areas such xenoliths of continental rocks are very scarce or not found in the lavas, the records that exist being non-proven. Hence has arisen the view that the foundation of the ocean is the same as that below the continental masses (or *sial*), namely, the sub-crustal layer of approximately basaltic composition known as the *sima*. Support for this deduction is afforded by the rate of propagation of earthquake waves.

Volcanoes on land, or below the sea in maritime areas, are frequently of explosive type, the rocks being blown to fragments, even to dust, and the products distributed over a relatively wide area. The fragmental materials there consist of broken-up crystalline or glassy lava or disintegrated continental rocks. In the case of submarine volcanoes it is reasonable to suppose that if explosive action occurs (although it may be damped down by the great load of the ocean), the products would be distributed throughout the deep-sea sediments at present being laid down. Now examination of large numbers of these deposits from all over the ocean floor brings out the fact that (if we except certain occurrences not very far from land, or wind-borne, as mentioned previously) the detrital minerals are those confined to igneous rocks and frequently to lavas. Minerals which could have been derived only from ancient sedimentary and metamorphic rocks, like those which make up the continents, are strikingly rare.

In the reports of the *Challenger* expedition some forty or more minerals were recorded from deep-sea deposits. All could have been derived from volcanic or intrusive rocks, or by growth in place: not one species is peculiar to continental rocks. The general impression given by the assemblage of minerals is intensified by

the oft-recorded presence of volcanic glass, tuff, palagonite and pumice. It would be inappropriate to a general review such as this to cite long lists of minerals or to describe their characters. It is probably of more interest to pass on to a brief consideration of some of the newly-constituted minerals now being formed on the sea-floor.

The problem of the mode of formation of such authigenic minerals in sediments has long fascinated geologists. The term authigenic denotes those minerals which have been formed in place, either contemporaneously with the sediment or at a later date, as distinct from the detrital minerals derived from the breaking-up of pre-existing rocks. The *Challenger* expedition discovered several authigenic minerals in deep-sea deposits, among them being glauconite, calcium phosphate, phillipsite and other zeolites, and manganese oxide (in manganese nodules). Among similar minerals believed in some cases to be of authigenic origin in ancient sedimentary rocks are soda-felspar (albite), potash-felspar (orthoclase and microcline), chlorite, epidote, pseudo-sillimanite, sphene, tourmaline and others, many being somewhat complex silicates. We still hope that a more intensive study of deep-sea sediments may throw light on their mode of origin and perhaps even reveal them in actual process of formation. Recently, two interesting and unexpected authigenic minerals new to science have been discovered by Messrs. F. A. Bannister and M. Hey, in samples collected by the *Scotia* from the Weddell Sea. From a careful study of the chemical composition, optical properties and X-ray spectrograms of some minute crystals found in the samples, these investigators have described "envelope" crystals of a calcium oxalate dihydrate from a depth of 2400-2700 fathoms. Somewhat similar crystals have been found in cells of plants, in the gall of mammals and fish, and in renal calculi. The chemical composition of these deep-sea crystals suggests an origin in which organic processes played a part. They appear to have been formed in muds on the sea-bottom, here in an area of increased salinity, corresponding to a slight undersaturation of calcium carbonate. A second group of crystals, similarly investigated, proved to have the composition of hydrated calcium citrate. The mineral has been named "Earlandite" in honour of the distinguished worker on foraminifera, who found them among the organic remains in samples he was examining. As calcium citrate has been found in plants, the presence of impurities such as Sr, Ba, Mg, Mn, Fe and Cu in the crystals may be significant. They came from a depth of 1410 fathoms and are of very restricted distribution; their origin is

conjectural. Bannister and Hey also found crystals of gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) in samples collected by the *Discovery* in the Weddell Sea in 1925, from a depth of 2800 fathoms. These gypsum crystals are of lenticular form up to 2 mm. in length. Although they have not previously been found in oceanic deposits, they have been known for many years to be authigenic constituents of the muds of the Mersey Estuary. Their formation in the Weddell Sea, like that of the two new minerals mentioned, points to peculiar conditions, perhaps of deep-sea lagoonal character.

In review, we see in the history of the earth the operation of repetitions of the geological cycle of rock-erosion (earth-sculpture), transport and deposition of sediment, and earth-movement leading to uplift. The interaction of the atmosphere, hydrosphere, and lithosphere, assisted by the thermal energy of the sun and the gravitational influence of the moon, results in the disintegrating work of frost, rain, wind, changes of temperature and the waves. The geologists' music of the spheres, though not without harmony, resolves itself into two clear refrains—of degradation on the surface of the exposed earth-crust, and synthesis on the sea-floor. But the process of reconstruction is effected with impoverished materials, for the decomposition of rocks and minerals proceeds both mechanically and chemically, and the soluble products pass out of the geological cycle to a considerable extent by accumulating in ocean-waters. All the known chemical elements are doubtless present in solution in the sea, but whilst calcium, silicon, iron, phosphorus, copper and others are extracted to a greater or less extent by organisms, elements such as sodium, chlorine and nitrogen accumulate. Against this increasing salinity of the sea, we must set off the formation of authigenic minerals on the sea-floor, but we have no reason for thinking that this process bulks largely. A certain amount of compensation for the loss of soluble materials from the geological cycle is afforded by the delivery from sub-crustal reservoirs of new rock-material by volcanic action, but we have no means of assessing its effect in restoring the balance.

Prediction is dangerous, but we may go so far as to ask ourselves whether the pointers in geology are suggestive of an irreversible trend to an uninteresting uniformity. On the earth's crust, the breaking-down of minerals and rocks, many of which are complex silicates, results in the liberation of the elements which form more soluble compounds, the alkalies, calcium, magnesium and so forth. The insoluble residues are ultimately of clayey character, such as hydrated silicates of aluminium and oxides of aluminium and

iron. Hitherto, we have distinguished between mechanical disintegration and chemical decomposition as processes of degradation, but recent investigations by Professor A. Brammall of the Imperial College of Science and Technology, as beautiful in their simplicity as they are significant in their wide repercussions, have abolished that distinction. For Professor Brammall has extended the work of Tamm and Stevens by demonstrating that fine grinding of most common rock-forming minerals brings them into a condition when they are hygroscopic and become partially dissociated in water, so that the elements of the alkalies and alkaline earths are liberated.

Ultimately, then, the finer suspended material which reaches the deeper parts of the sea consists almost exclusively of simple hydrated silicates of aluminium in a fine state of division, that is, clay. In addition to this detrital accumulation there are the deposits of calcareous and siliceous materials formed by organisms. It would seem that there is thus an almost complete differentiation into a solution (sea-water) rich in its diverse dissolved elements, and "dull" floor-deposits of very restricted composition. Such must be the tendency unless synthetic processes are proceeding in the depths to form new minerals. J. L. Thiébaud claimed to have proved in 1925 that marine clays were usually composed of complex silicates of aluminium, iron, potash, calcium and magnesium, in contradistinction to fresh-water clays which are largely silicates of aluminium with a little iron and magnesium. We may ask then—or formulate the question as a problem for investigation—whether the elements in sea-water are being restored to the accumulating simple clays in the depths of the sea, a region termed by Correns "Nature's laboratory," although perhaps to speak of "factory" would be more appropriate. But in the meantime even our small knowledge of the processes at work convinces us, with Shakespeare, that "clay and clay differ in dignity."

TRANSFORMATIONS OF ATOMIC ARRANGEMENT IN ALLOYS

By E. J. WILLIAMS, D.Sc.

The University of Liverpool

AN article by Dr. A. J. Bradley [1], published in this Journal about three years ago, described the effect of heat treatment on the arrangement of the atoms in certain alloys. At low temperatures the atoms of the different metals in the alloy arrange themselves in an orderly way, such that atoms of one kind are interspersed with those of another as far as possible. At high temperatures this order tends to disappear, and in certain cases the various kinds of atoms are randomly distributed as if there were no difference between them. This transformation of the atomic arrangement in an alloy due to change of temperature, and its association with anomalies in the specific heat and the electrical resistivity of the alloy, are now well established, and apart from details the phenomena have been satisfactorily explained on the basis of atomic and kinetic theory. This theoretical treatment is of particular interest in that it shows the possibility of applying atomic and kinetic theory in a quantitative way to metallurgical problems. It is to be hoped that it will prove the forerunner of further applications in metallurgy, where there has so far been little guidance from physical theory of this kind. In the present article, which may be regarded as a sequel to that of Bradley's, a general account of the "order-disorder" transformation is given, of its theoretical treatment and of recent experimental work.

In a solid the points representing the mean positions of the atoms are regularly arranged in space. They form a lattice which conforms to some simple geometrical pattern. If the solid is a chemical compound then in addition to this regularity in the spatial distribution of the position of the atoms, or what may be called the *atomic sites*, there is a regularity in the way in which these sites are occupied by the different kinds of atoms. This order is such that if, for instance, we proceed along a line of lattice points

the atoms of different kinds recur at regular intervals. This necessitates and goes hand in hand with the existence of a simple ratio between the numbers of the different kinds of atoms present. Both circumstances arise from the fact that the cohesive forces keeping the substance together are forces of attraction between one kind of atom and another. An orderly arrangement such that certain atoms are next to each other in the lattice is in fact essential to the very existence of the substance. As an example we may take sodium chloride. Here the atomic sites form a simple cubic lattice. The binding is due to the attraction between the positively charged sodium atoms and the negatively charged chlorine atoms. This ensures an orderly arrangement of the atoms such that along the continuation of a line joining one atomic site to the one nearest to it sodium and chlorine atoms occupy alternate places.

An alloy differs from a chemical compound in that the atoms of the different metals constituting it are not necessarily present in a simple numerical ratio—the ratio may have a continuous range of values—nor does the orderly arrangement of the different atoms amongst the atomic sites always exist. These are experimental facts which have been conclusively proved by X-ray analysis of the atomic structure of alloys. The general explanation is that, in contrast with a chemical compound, the cohesive forces in an alloy are forces of attraction between the ionised atoms on the one hand and the free electrons resulting from their ionisation on the other. The atoms of different kinds play the same rôle—they provide free electrons and are then attracted by them.¹ There are of course differences of degree between the various kinds of atoms present. Atoms of one kind may provide a different number of free electrons per atom from the other kind of atoms present. Besides leaving the different kinds of atoms with different charges this would also make the density of the free electrons depend very much on the atomic ratio. Even if the degree of ionisation is the same the outer electronic structure of the different kinds of atoms will differ to some extent, giving them, in effect, a different size. It is these quantitative differences that limit the range of possible values of the atomic ratio, and which tend to make the different kinds of atoms in an alloy distribute themselves in an orderly fashion on the lattice of atomic sites. The important point is that these differences are not what is responsible for the existence of the alloy, and the ordering forces to which they give rise are weak in comparison with those in a chemical compound.

¹ A full account of the nature of cohesion in metals and alloys was given in an article by Professor N. F. Mott in the January number of this Journal.

Alloys of iron and aluminium provide a good example of the above features. The composition of such alloys can be varied continuously from pure iron to the composition FeAl . Over the whole of this range the alloy is strictly homogeneous. No additional phase is formed, the arrangement of the atomic sites remaining the same throughout, *viz.*, body-centred cubic. The addition of aluminium merely increases the fraction of the sites occupied by aluminium atoms.

When the atomic ratio in an alloy is incommensurate then evidently an absolutely regular distribution of the atoms amongst the atomic sites is impossible. What is important, however, is that even when the ratio is *simple* such regularity does not necessarily exist. The iron-aluminium alloy with the simple composition Fe_3Al is an example. At room temperature this alloy (if in equilibrium) is ordered. Every fourth atom along a diagonal of the cubic structure is aluminium, the sequence being . . . $\text{AlFeFeFeAlFeFeFeAlFeFeFe}$. . . At high temperatures this regularity breaks down, some of the aluminium atoms leaving their positions of "order" to replace some of the iron atoms in the 3rd, 7th, 11th . . . positions along this line, a possible sequence being . . . $\text{AlFeFeFeFeFeAlFeAlFeFeFe}$. . .

The evidence for the disordering in Fe_3Al was obtained by Bradley and Jay [2] using the method of X-ray analysis. In this method the onset of order is signified by the creation of new orientations at which a crystal of the alloy will reflect X-rays. In addition to the lattice of atomic sites the ordered arrangement of the atoms amongst these sites defines another lattice, with a bigger spacing (depending on the distance between similar atoms). This has been called a *superlattice*, and it is this that gives rise to the new reflections.

The demonstration of the effect of temperature on the order of atoms in an alloy by this direct method of X-ray analysis was first made by Johannsen and Linde [3] in 1925. They investigated an alloy of copper and gold with the simple composition Cu_3Au . The atomic sites in this alloy form a face-centred cubic lattice. Such a lattice may be regarded as a superposition of four identical interpenetrating simple cubic lattices. Johannsen and Linde found that at high temperatures (about 500°C .) the gold and copper atoms are randomly distributed amongst the atomic sites. On the other hand at 300°C . a superlattice forms, the gold atoms segregating to one of the four component lattices, the copper atoms to the other three.

Before these experiments there was no direct evidence for the

setting in of a more ordered arrangement of the atoms in an alloy as its temperature is reduced. The existence of the phenomenon had, however, already been inferred by Tamman [4] in 1919. The electrical resistivity of the alloy Cu_3Au was known to decrease rapidly with decreasing temperature in the neighbourhood of 400°C . (the curve in Fig. 1 represents the results of recent experiments by Sykes and Evans [5]). To explain this Tamman assumed that in the region of 400°C . the atoms of Cu_3Au rearrange themselves in a more orderly fashion, and that the ordered arrangement gives the alloy a much smaller resistance. As mentioned above the experiments of Johannsen and Linde bear out this hypothesis, though their observations do not prove that the formation of a

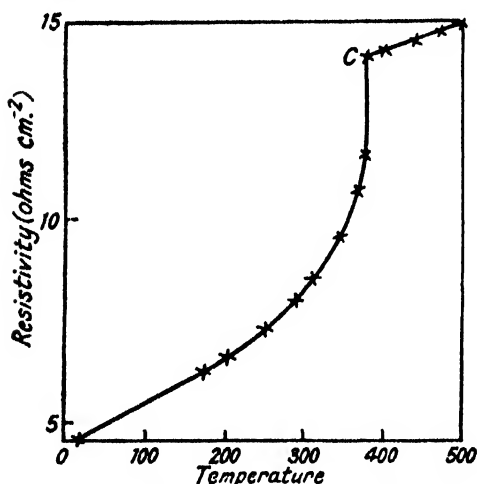


FIG. 1.—Observed variations of resistivity of Cu_3Au with temperature (Sykes and Evans).

superlattice in their experiments (which indicates ordering) takes place in precisely the same temperature region as that in which the resistance drops. Subsequent work, and especially the recent experiments of Sykes and Jones [6], leaves no doubt about this, and therefore on experimental grounds the abnormal decrease in resistivity with decreasing temperature is certainly the result of ordering. It might also be mentioned that it is one of the fundamental

requirements of the quantum-mechanical theory of conduction that such ordering should reduce electrical resistance.

By virtue of this connection between the resistance and the order, resistance measurements such as those represented in Fig. 1 can be used to make a closer study of the process of ordering than is practicable by the direct method of X-ray analysis. These resistance measurements, in fact, reveal in a striking fashion the outstanding property of the phenomenon. This is the existence of a critical temperature at which ordering suddenly starts when the alloy is being cooled. It is represented by the point C in the resistance-temperature curve in Fig. 1. On the low temperature side of this point the curve falls rapidly, indicating the sudden onset of order at a sharply defined temperature. The actual

critical temperatures for certain alloys are 385° C. for Cu₃Au, 470° C. for CuZn, and 550° C. for Fe₃Al.

The existence of a critical temperature in the order-disorder transformation is also made evident by a discontinuity in the specific heat of the alloy. The curve in Fig. 2 represents recent experimental results obtained by Sykes [7] for CuZn. In all cases the sudden rise in the specific heat takes place at the same temperature as that at which there is a drop in electrical resistance, showing that like the latter it is the result of a disorder-order transformation in the alloy.

The large specific heat below the critical temperature means

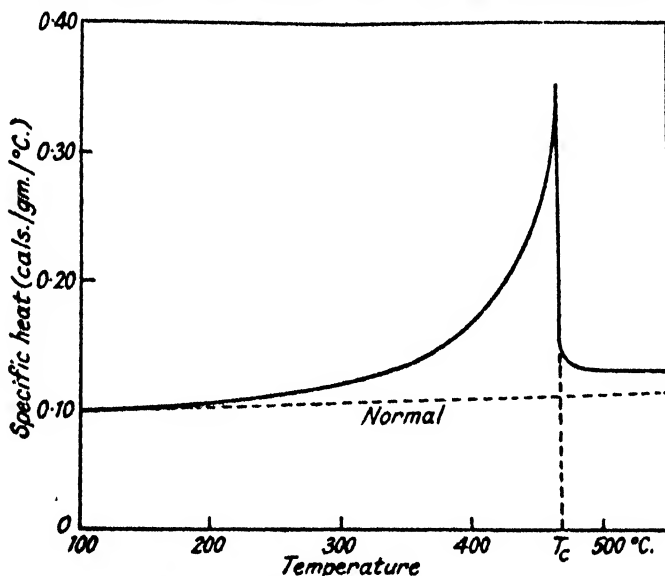


FIG. 2.—Observed variation of specific heat of CuZn with temperature (Sykes).

that the ordering which takes place as the alloy is cooled is accompanied by the evolution of energy. It shows that the ordered state is one of lower internal energy than the disordered state. This, however, also follows from the simple fact that order sets in at all. For thermal agitation always promotes disorder, and should that state be also the state of lower energy there would be no circumstance tending to set up any other régime. Disorder would exist at all temperatures. To account for order setting in at all we have to assume that the internal energy of the alloy decreases with increasing degree of order. We may accordingly think of an "ordering" energy (V) which may be defined as the decrease in internal energy of the alloy when two atoms change

places on the lattice so as to increase the degree of order. The equilibrium state of the alloy will then depend on the relative values of V and the energy of thermal agitation. The latter, per atom, is of the order of kT where k is the gas constant per atom.

An interesting and important aspect of the order-disorder transformation is the limited rate at which it can proceed. If for instance the temperature of an alloy is suddenly changed from T' to T'' the equilibrium atomic arrangement characteristic of T'' will not be set up immediately. There is a certain degree of lag. For CuZn in the region of the critical temperature this lag—or what is often called the “time of relaxation”—is only a fraction of a second. For Cu₃Au on the other hand it is of the order of several hours. The existence of such a lag arises from the finite rate at which the atoms of the alloy change places on the lattice. This interchange of places is of course the essential mechanism of the order-disorder transformation. It is also responsible for certain types of intermetallic diffusion. It is of interest that when an atomic interchange is taking place the atoms concerned are at that instant not situated at the regular lattice points. There is a kind of local breakdown of crystal structure. It may be shown, however, that the fraction of atoms in the alloy which at any instant are taking part in these interchanges is negligible,¹ and the solid structure is not seriously threatened by these movements even at temperatures near the melting-point.

The existence of a finite time of relaxation, and its rapid increase with decreasing temperature is of great importance in the study and application of the order-disorder transformation. For instance, by cooling an alloy through the region of the critical temperature in a time small compared with its time of relaxation in that region the disordered state can be preserved down to room temperature. At this lower temperature the approach to equilibrium is so slow that the state is virtually permanent. In this way it is possible to investigate the atomic arrangement characteristic of high temperatures by measurements on a cold specimen of the alloy. This has been the principle of most of the X-ray investigations hitherto made. Another consequence of the finite time of relaxation is that an alloy cooled and reheated through the critical region will show hysteresis effects, the magnitude of which will depend on the ratio of the time of relaxation to the times of heating and cooling. If

¹ The time an atom takes to move to a new site when such a movement takes place is of the order of a period of oscillation, while the time it stays in the same site is of the order of the time of relaxation. The above fraction is the ratio of these times.

the rates of change of temperature are sufficiently slow to enable the alloy to attain its equilibrium configuration at every temperature, then there is no hysteresis and the transformation is perfectly reversible.

Space prevents further discussion of this more practical side of the order-disorder transformation. We shall now proceed to consider the general theory of the more important features of the order-disorder transformation for an alloy *in equilibrium*.¹

Existence of a Critical Temperature.—It is at first difficult to see why, as an alloy is cooled, the ordering forces completely fail to set up any degree of order until the sharply defined critical temperature is reached. We have referred to an ordering energy, V , and the existence of such energy would mean *some* degree of order however high the temperature.

The solution of the difficulty lies in the fact that when there is no order at all, *i.e.* when the different atoms are randomly distributed on the lattice, there is statistically no ordering force, *i.e.* $V = 0$ [8, 9]. To see this let us consider an example. In CuZn the atomic sites form a body-centred cubic lattice. This can be regarded as two inter-penetrating simple cubic lattices, the lattice points of the one (α) being at centres of the elementary cubes formed by the lattice points of the other (β). In the completely ordered alloy the Cu atoms are at the points of one lattice, which we may arbitrarily suppose to be the α -lattice, while the Zn atoms occupy the other (β). A copper atom is then surrounded by 8 zinc atoms and vice-versa. If a copper atom in this ordered structure is interchanged with a zinc atom it experiences a complete change of neighbours. It will now be surrounded by copper atoms. There is thus a very big difference between its position of "order" on the α lattice, and a position of "disorder" on the β lattice. Under these conditions the ordering force is very strong. Now when the Cu and Zn atoms are randomly distributed all lattice points are statistically identical, and there is no tendency for the Cu atoms for instance to occupy points on the α -lattice any more than points on the β -lattice. There is nothing to distinguish the two lattices, so that the ordering force vanishes, *i.e.* $V = 0$. It is only when atoms of one kind already occupy one lattice more than the other that the two lattices are distinguishable.

This result—that when the alloy is completely disordered there is no tendency to produce order—means that complete disorder is an equilibrium state whatever the temperature. It must, how-

¹ For a detailed discussion of the various theoretical investigations of this problem see reference [11].

ever, be a state of stable equilibrium if it is actually to exist.¹ To test its stability suppose a small degree of order, δS , be created, so that copper atoms occupy one component lattice (α , say) to a slightly greater extent than the other.² This will distinguish the two lattices and give rise to a small ordering energy δV . The disordered state is then stable if δV is too small to maintain the degree of order δS . Whether this is so, or not, depends on the strength of the disordering force, i.e. on the thermal agitation.³ This decreases uniformly with the temperature and accordingly there will be a temperature, T' , at which the ordering energy δV , set up by a small degree of order δS , is just sufficient to maintain that degree of order against thermal agitation. Above T' thermal agitation predominates and the alloy returns to its disordered state, which is therefore a state of stable equilibrium. At T' it is one of neutral equilibrium—ordering is incipient. Below T' δV is more than sufficient to maintain the small degree of order δS which gives rise to it. The order therefore increases further, so that the disordered state is now unstable. This, in general terms, is the explanation of the existence of a critical temperature in the phenomenon of order-disorder transformations in alloys. It essentially depends on the recognition of the fact that the ordering force vanishes with the degree of order.

It is of interest that there are at least two other critical temperature phenomena very similar to that under discussion. One is ferromagnetism. Here the Curie-point is a critical temperature above which iron is non-magnetic, the elementary "magnets" being randomly orientated. As the temperature is reduced the magnets suddenly start to align themselves at the Curie-point. The explanation is in principle exactly the same as that of the critical temperature in alloys. When the elementary magnets are randomly orientated there is no systematic force tending to make them point in any particular direction, because all directions are statistically equivalent unless a certain degree of alignment already exists. This is very similar to the state of affairs in alloys where we have no ordering force in the disordered alloy, because the component lattices to which the different atoms are segregated when the alloy is ordered are equivalent when there is no order

¹ This condition is not always sufficient but this point can be neglected here.

² In an actual alloy such displacements from the state of complete disorder take place through statistical fluctuations.

³ It does not depend on the actual magnitude of the displacement. For while the ordering energy δV is proportional to δS , the ordering energy required to maintain δS is also proportional to δS . It is the ratio $\delta V/\delta S$ that matters.

at all. The other phenomenon of this kind concerns the orientation of dipole molecules in certain inorganic compounds [10]. Regular orientation and the cessation of rotation of the dipoles start at a definite critical temperature. Here again the ordering force, which is the macroscopic electric field of the oriented molecules, vanishes when there is no orientation.

For a quantitative treatment of the order-disorder transformation in alloys the degree of order must be clearly defined. Let the alloy consist of two metals A and B whose atoms are present in a simple ratio $r : (1 - r)$. When there is complete order the A atoms occupy one set of atomic sites (α) and the B atoms another set (β), the two sets of sites forming two interpenetrating lattices. In this ordered state the probability that an α -site is occupied by an A atom is unity. When there is complete disorder it is evidently equal to r . When there is partial order it will have some intermediate value, p , and we define the degree of order as

$$S = (p - r)/(1 - r) \quad . \quad . \quad . \quad . \quad (1)$$

This makes S unity for complete order, and zero for complete disorder.

The value of S at any given temperature depends on the ratio of the ordering energy, V , to the energy of thermal agitation, and can be calculated from kinetic theory. In this calculation it must, however, be remembered that the ordering energy is itself controlled by the degree of order. We have indeed seen that the vanishing of V as complete disorder is approached is the reason for the existence of a critical temperature. In the calculations which have been made along these lines [9] a simple proportionality has been assumed between V and S , i.e.

$$V = V_0 S \quad . \quad . \quad . \quad . \quad . \quad (2)$$

This follows naturally if we suppose that there is a greater attraction between unlike atoms than between like atoms, and that the forces between two neighbouring atoms are independent of the degree of order (cf. equation 5 below).

The variation of the degree of order with temperature to which the above relation gives rise, in the case of $r = \frac{1}{2}$ (e.g. CuZn) is shown by the curve (a) in Fig. 3 [9]. The point A marks the critical temperature. Below A the ordering is so rapid that it is within 25 per cent. of being complete at a temperature of $0.8T_c$.

The rapid rise in the order-temperature curve below the critical temperature is in qualitative agreement with the observed jump in the specific heat of the alloy and with the rapid decrease in its electrical resistance in this region. A quantitative comparison

with the latter is at present not possible because the exact relation between the electrical resistance and the degree of order is not known. The thermal behaviour can, however, be directly calculated from the order-temperature curve and the value of V_0 (equation 2). A fairly close comparison with experiment has been made for CuZn [11]. As regards the total energy evolved during the process of ordering, its calculated value for this alloy is 740 calories/gm. atom, the experimental value obtained by Sykes [7] is 600 ± 50 . The actual rate at which this energy is evolved—that is, the shape of the curve representing the variation of anomalous specific heat with temperature, as distinct from the total area under the curve—is not so satisfactorily given by the theory. This, however, is to be expected, as the shape of the specific heat curve is very sensi-

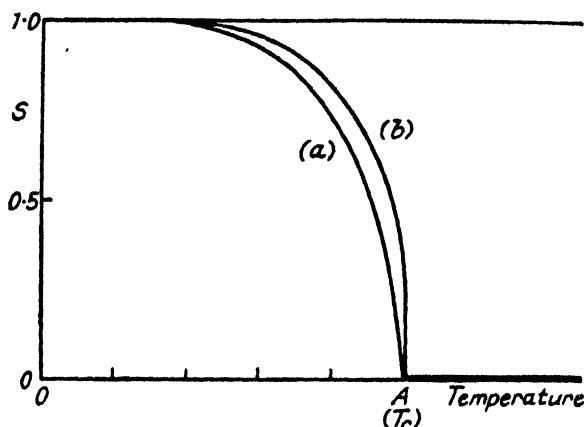


FIG. 3.—Calculated variation of degree of order with temperature (Bragg and Williams). (a) for $r = \frac{1}{2}$; (b) for $r = \frac{1}{4}$.

tive to the form of the relation between V and S , while the assumption that the latter is linear (equation 2) is rather arbitrary. The discrepancy is such that the calculated jump in the specific heat at the critical temperature is too small. The theory can be formally rectified by assuming a slightly faster increase of the ordering energy with degree of order. Actually $V \propto (S + gS^2)$ where $g \sim 0.25$ would appear to be a sufficient modification [12].

It is important to notice that whether an alloy exhibits an order-disorder transformation or not depends on the value of V_0 , because this determines the critical temperature. The calculated critical temperature in degrees absolute is roughly $0.2V_0/k$, the numerical factor depending to some extent on the type of structure, *i.e.* on r , but not very much. If now V_0 is so large that $0.2V_0/k$ is greater than the *melting-point*, the alloy will remain

ordered at all temperatures, resembling a chemical compound. On the other hand, if $0.2V_0/k$ is small—less than a temperature T_f of the order of 600°K .—the alloy will in practice always be completely disordered. T_f marks the region of temperature at, or below, which atomic interchanges take place too infrequently to enable the atomic arrangement to change appreciably in any reasonable time, even though it be far from the equilibrium arrangement. At T_f —which depends to some extent on the alloy and is of course not sharply defined—the atomic arrangement becomes permanently “frozen in.” Though an ordered arrangement becomes an equilibrium state at lower temperatures it will not be formed. Thus an order-disorder transformation will be observed only if the critical temperature ($\sim 0.2V_0/k$) is greater than T_f , and less than the melting-point of the alloy. This means a value of V_0 between about 0.2 and 0.5 volts. This condition is what limits the number of alloys which exhibit the phenomenon.

The Ordering Force and Local Order.—The ordering force in an alloy may be attributed to the affinity between unlike atoms being greater than that between like atoms. This tends to make unlike atoms occupy neighbouring points on the lattice structure, giving rise to what may be called an order of neighbours. We may define such order as $\sigma = (m - m_1)/(m_2 - m_1)$, where m is the number of pairs of unlike neighbours in the alloy, m_1 is the value of m for complete disorder, and m_2 is its maximum possible value. This order of neighbours is not the same as the order we have hitherto considered and denoted by S (defined by equation 1). The latter represents the segregation of the different kinds of atoms to different component lattices, thereby forming a superlattice. This "superlattice" order is what sets in at the critical temperature. Such order of course implies order of neighbours. Actually the order of neighbours, σ , corresponding to a superlattice order, S , may be shown to be [12]

$$\sigma_i = S^i \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

The point of interest is that the order of neighbours in general exceeds σ_c on account of a local association of unlike atoms over and above the superlattice effect. For example, above the critical temperature no superlattice order exists, but this evidently does not preclude unlike atoms from associating, at least to some extent. Denoting this local order of neighbours by σ_l the total order of neighbours is

$$\sigma = \sigma_s + \sigma_l = S^2 + \sigma_l \quad . \quad . \quad . \quad (4)$$

The existence of this local order does not affect the general explanation which we have already given for the onset of superlattice order at a sharply defined temperature. This explanation depends on the vanishing of the superlattice ordering energy (V) with the degree of superlattice order. This is still true because the local order, σ_i , does not contribute to the energy V . If, for instance, following Bethe [13], we assume that the ordering is due solely to the forces between neighbouring atoms (which gives local order its extreme significance) the average value of the ordering energy V may be shown to be given by [12]

$$V = r(1 - r)Z(V_{aa} + V_{bb} - 2V_{ab}) \times S \quad (5)$$

Here r has its earlier meaning. Z is the number of nearest neighbours for every atom (8 for a body-centred cubic lattice such as CuZn). V_{aa} is the mutual energy of two neighbouring A atoms, V_{bb} of two B atoms, and V_{ab} the mutual energy of two unlike neighbours. The important point regarding the critical temperature is the vanishing of this expression for V with S .

Though local order does not affect the general character of the order-disorder transformation, its recognition and treatment by Bethe [13] marks an important step forward in the theory of these transformations. It has also brought to light a new feature, viz. a small abnormal specific heat *above* the critical temperature. This is difficult to test quantitatively but that it does exist is borne out by Sykes' experimental results for CuZn. These are represented in Fig. 1, where the specific heat above the critical temperature is seen to be distinctly above the normal.

Transformation with Latent Heat.—The theory of the order-disorder transformation, assuming $V \propto S$ (equation 2), leads to the interesting result that for alloys with $r = \frac{1}{2}$, such as Cu₂Au, a finite degree of order is established at the critical temperature, [9, 11] in contrast with the results for alloys with $r = \frac{1}{3}$ (such as CuZn). The actual calculated variations of the degree of order with temperature for these two types of structures are represented respectively by the curves (b) and (a) in Fig. 3. The establishment of a finite degree of order at the critical temperature, for $r = \frac{1}{2}$, is represented by the vertical rise in the curve (b) at T_c . This result means that as such an alloy is cooled a finite amount of heat is liberated *at* the critical temperature, resembling the phenomenon of "latent heat" in a liquid-solid transformation.

Careful observations have recently been made by Sykes and Jones [6] on the order-disorder transformation in Cu₂Au, with the

object of testing this latent heat¹ prediction of the theory. They took special care to obtain results which refer to the alloy in its equilibrium state. This is very important because if the alloy is cooled quickly the finite amount of heat which might otherwise be given out at the critical temperature will be spread out over a range of lower temperatures. The results obtained by Sykes and Jones show fairly conclusively that the transformation in Cu₃Au is one with latent heat, in agreement with the calculations. Their estimate of its magnitude is 130 calories per gram-“molecule.”

The curves (a) and (b) in Fig. 3 were calculated neglecting the effect of local order. The same difference between $r = \frac{1}{2}$ and $r = \frac{1}{4}$ however also comes out of the theory when this type of order is allowed for [14]. In both types of calculations the existence of a latent heat for $r = \frac{1}{2}$ is the result of a peculiarity in the variation of the entropy of the alloy with degree of order rather than in the variation of its internal energy with order. This is in contrast with the phenomenon of melting, where the discontinuous change of state from solid to liquid is probably due to the very high internal energy of any intermediate state and not to a low entropy.

In concluding this article we may refer to some of the problems connected with the order-disorder transformation which have yet to be dealt with or whose existing treatment is not complete. One is the behaviour of alloys whose composition departs from a simple atomic ratio, the main questions being the dependence of the critical temperature on the composition, and the possible separation into two phases during cooling. What is desired in this connection is a theory based on some simple and natural assumptions regarding the forces between individual atoms. A point of minor importance is the dependence of the entropy of atomic vibration on the degree of order. This must be investigated before the existing experimental results for the thermal effects can be accurately interpreted.² Problems of more theoretical interest are

¹ The term “latent heat” is really not an appropriate one for distinguishing this type of transformation from that for $r = \frac{1}{4}$. In both cases there is *latent* heat in the true sense of the word—being the heat latent in the disordered alloy. The term is used here to denote the liberation of a finite amount of this latent heat at *one* temperature.

² This could be investigated for instance by observations on the specific heat of the quenched disordered alloy and of the ordered alloy at very low temperatures, in order to determine the difference $\delta\theta$ between their respective characteristic temperatures. The increase in the entropy of vibration when disordering takes place is then, under certain assumptions, equal to $3\delta\theta/\theta \times k$. The corresponding increase in the entropy of the atomic arrangement is

the dependence of electrical resistance on the degree of order, and the absolute magnitude of the ordering energy V_0 (which depends on the mutual energy of different atoms in the alloy). These come within the scope of the quantum-mechanical theory of metals and of metallic conduction.¹ Lastly we may mention the dynamical problem of the approach to equilibrium. Recent experiments by Sykes and Jones [6] on Cu₃Au have cleared up some of the difficulties regarding this process, but there are still some obscure points, such as the relation of the rate of change of atomic arrangement to the rate of inter-metallic diffusion.

REFERENCES

1. Bradley, *Science Progress*, **28**, 253 (1933).
2. Bradley and Jay, *Proc. Roy. Soc., A*, **136**, 200 (1932).
3. Johannsen and Linde, *Ann. Physik*, **78**, 439 (1925).
4. Tamman, *Z. Anorg. Chem.*, **107**, 1 (1919).
5. Sykes and Evans, *Journ. Inst. of Metals*, **58**, 255 (1936).
6. Sykes and Jones, *Proc. Roy. Soc., A*, **157**, 213 (1936).
7. Sykes, *Proc. Roy. Soc., A*, **148**, 422 (1935).
8. Gorsky, *Z. Physik*, **50**, 64 (1928).
9. Bragg and Williams, *Proc. Roy. Soc., A*, **145**, 699 (1934).
10. Fowler, *Proc. Roy. Soc., A*, **149**, 1 (1935).
11. Bragg and Williams, *Proc. Roy. Soc., A*, **151**, 540 (1935).
12. Williams, *Proc. Roy. Soc., A*, **152**, 231 (1935).
13. Bethe, *Proc. Roy. Soc., A*, **150**, 552 (1935).
14. Peierls, *Proc. Roy. Soc., A*, **154**, 207 (1936).

approximately $0.7k$, the exact numerical factor depending on the structure. The ratio of the two is accordingly about $4\theta\theta/\theta$, which may in some cases be quite appreciable.

¹ *Added in Proof.* Recently Mott (*Proc. Phys. Soc.*, **49**, 258, 1937) has made an estimate of the difference in energy between the disordered and ordered alloy of CuZn. This difference is closely related to V_0 . Its theoretical value according to Mott's calculations is 0.040 electron-volts per atom of the alloy. The observed evolution of heat due to the ordering which takes place below the critical temperature is 0.025 e.v. [7, 11]. To compare with the theoretical estimate we must add to this about 0.005 e.v. due to the ordering which takes place above the critical temperature. The total is then 0.030 e.v., in satisfactory accord with Mott's approximate estimate. Mott also gives reasons for supposing that the difference between the mutual energies of unlike and like atoms increases with the degree of order. This also fits in with the experimental facts, which indicate that this energy difference varies approximately as $1 + 0.25\sigma$, where σ is the order of neighbours [12]. This variation with σ approximately corresponds to the variation of the ordering energy V with S ($1 + 0.25s$), already mentioned in this article.

THE LANGUAGE OF BEES ¹

BY PROFESSOR K. VON FRISCH

The University of Munich

To understand the language of bees it is first necessary to know something about the senses of bees. The senses of bees are of special interest for biologists, because bees are flower-visiting insects. Since the time of the German naturalist Chr. K. Sprengel, more than 140 years ago, we distinguish two main types of flower in the higher plants. A great many plants have small, scarcely visible, blossoms without any scent, and their pollination is effected by the wind. Such blossoms have plenty of pollen, which is spread by the wind and comes by chance to other blossoms of the same species. The other plants have conspicuous, brightly coloured blossoms, or a striking scent, or both colours and scent. We call them flowers. Such flowers produce honey, and they are therefore visited by feeding insects, which effect the pollination quickly and surely by flying from one flower to the next one of the kind. It seems probable that the flowers have their colour and scent to make them more striking for the visitors. In this way, the insects can more easily find them and get their food, and the pollination of the flowers is guaranteed.

Sprengel's view was not accepted by all naturalists. There was a controversy on this subject for many years, especially concerning the function of the colours of flowers. Even twenty-five years ago Professor Hess asserted that bees and all other insects are colour-blind. If this is true, the colours of flowers cannot be of the biological significance that Sprengel thought. I tried therefore to find out whether bees can distinguish colours.

The honey bee is a social insect. It lives in a beehive. In such a hive there are about 70,000 bees, only one of which is a fully developed female, the queen, the only egg-laying insect of all the inhabitants of a beehive. The males are plumper, and very stupid and lazy. Most of the inhabitants are worker bees. They are not able to produce eggs under normal circumstances. But

¹ A Lecture delivered at University College, London, March 1937

they do all the work in the hive, they feed the larvæ, they build the wax combs, they are the charwomen in the hive, and only the worker bees fly out to get honey and pollen as food for the inhabitants.

Such food-collecting worker bees we take for our experiment. We use the scent of a little honey to attract some bees to our experimental table, and feed them, for instance on a blue cardboard. They suck up the food and, after homing, give it to other bees in the hive. Then they return to the good feeding-place they have discovered. We let them do so a while, and then we take away the blue cardboard with honey and put a new clean blue cardboard on the left, and a red one on the right of the feeding-place hitherto existing. Should the bees remember that they found the food on a blue cardboard, and should they be able to distinguish between blue and red, they would fly to the blue colour. That is exactly what happens.

This is an old experiment, already carried out by the English naturalist John Lubbock. It proves that bees can distinguish colours. But it does not prove that bees have colour-sense. It is not the same thing. There are (very rarely) totally colour-blind men. They see all things in much the same manner as we see them in an ordinary photograph. They can distinguish between red and blue, for red is very dark to them and blue much lighter. From our experiment we cannot conclude whether the bees have distinguished red and blue by the colours or by the shades, as a colour-blind man does.

For a colour-blind human eye every colour is a grey of a distinct degree of brightness. What the brightness may be for the eye of a colour-blind insect we do not know. We therefore make the following arrangement.

We place a blue cardboard on a table, and beside it and around it grey cardboards of all shades from white to black. On each card there is a little watch-glass, but only the glass dish on the blue cardboard contains food (sugar water). In this way we train the bees to the colour blue. Bees have a very good memory for place. We therefore change the respective positions of the cards very often. But the food is always placed on the blue cardboard, and the colour therefore indicates invariably where the food is to be found.

After some hours or after some days we can make the decisive experiment. The cardboards and glass dishes soiled by the bees are taken away. We put on the table a new, clean series of differently shaded grey cardboards, and anywhere between them we put

a clean blue cardboard with an empty glass dish. The bees remember the blue colour and alight only on the blue cardboard. They distinguish it without hesitation from all degrees of grey. They therefore have a colour sense.

Training to orange, yellow, green, violet, or purple gives the same good results. But bees trained to scarlet red alight not only on the red paper but in the same manner on black and all dark papers in our arrangement. Red and dark are the same for bee's eyes. Bees are red-blind. That is very interesting. We understand why scarlet red bee-blossoms are so rarely found. There are very many red flowers in America, for instance, but only in bird-blossoms. Birds' eyes are very sensitive to red. In Europe there are some plants with red flowers, but their pollination is—with few exceptions—effected by certain butterflies. These butterflies are the only insects which are not red-blind. There is an exception to the rule—the poppy, the flowers of which are visited by bees although they are scarlet red. But these flowers reflect many ultra-violet rays. Bees are able to perceive ultra-violet rays. Ultra-violet is a special colour for them, distinguishable from blue and all other colours. It is evident that the colours of flowers have been developed as an adaptation to the colour-sense of their visitors.

One more thing is of interest to biologists. We make the following experiment. We train bees to blue, and then we put all the different-coloured cardboards on the table. The bees seek the blue colour, but are unable to find it with certainty; they confuse it with violet and purple. Bees trained to yellow confuse the yellow with orange and green. It is important to notice that they cannot distinguish as many colour shades as we can.

Bees restrict their visits to certain flowers. A given individual on its trip always visits definite species of flowers. That is of advantage for the bees, which on all flowers of the same kind meet with the same mechanism of blossom and save time through being acquainted with it; it is also of advantage for flowers, for their pollination depends on bees coming from other flowers of the same species. If the bees specialise in certain flowers, they must be able to distinguish the different kinds of flowers. Biologists formerly thought that it was the difference of colour shade which enabled bees to distinguish them. Now we hear that bees cannot distinguish so many different shades of colour as we can. They must therefore have other means of distinguishing the different kinds of flowers. It might possibly be the scent of flowers. Such considerations led me to my work about the sense of smell in bees.

The result was that we found that the scent of flowers is the most important factor that enables bees to recognise the different flowers. We can train bees to scent just as we trained them to colour. On a table we place some cardboard-boxes, each of which can be opened from above. There is a hole in the front of the box. In only one of the cardboard-boxes is there a feeding-glass, and into the same box we drop a little essential oil. The other boxes are without scent and without food. We change the position of the food-box frequently in order to avoid a training to place. The scent guides the bees to the food. After some hours we put away all the boxes soiled by the visiting bees, and make a new arrangement with boxes not yet touched by bees. In one of them, we drop a little of the scent we have adopted for training purposes, but there is no food in it. The bees fly to the boxes, smelling around the holes, but they only enter the scent box. It is therefore clear that they can smell this scent, and that they use it as a guide to the food place.

The sense of taste is a very closely allied sense. It is also a chemical sense. But for taste it is necessary that the mouth parts should come in contact with a solution. If it is a sweet solution, the bees suck it up. Indeed, the bees are rather fastidious about sweetness. If it is a solution containing 20 per cent. saccharose, they suck it up. If it contains 10 per cent. we can see that in bees as in men there is an individual difference in taste. Some bees drink, others hesitate, and others refuse it. If it contains 5 per cent., they taste it and refuse to accept it. In this connection it is interesting that nectar in bee blossoms is always a solution with a high content of sugar; on an average nectar contains about 40 per cent. sugar.

Training to taste is impossible. Either they drink the solution, or they refuse it. Nevertheless, it is possible to find out something about the quality of their sense of taste. But I cannot explain the methods in a few words. Let me only say that bees can distinguish the same qualities as we can—sweet, bitter, sour, salty. But not all substances we consider sweet are sweet for bees. Many sugars very sweet for us are tasteless to bees, *e.g.* lactose, cellobiose, raffinose, etc. And the artificial sugars saccharin and dulcin are not sweet but are tasteless to bees.

It is much easier to find out more facts about the quality of the sense of smell in bees, because we can train to a certain scent. Thus, for example, we provide all the boxes with different scents. The bees trained to a certain scent are able to pick out the training scent from 30 or 40 different scents. Furthermore, we can dilute

the training scent more and more, and the result is that for the sense of smell in bees the limit is quite the same as for human beings. The scent of most flowers therefore cannot attract from a great distance. The colour of flowers has the advantage of attracting bees from a greater distance. Scent has the advantage of being perfectly distinct for each species of flower. And so the scent permits the definite recognition of flowers from near by.

In earlier times biologists thought that the function of the scent of flowers was to attract insects and to enable them to find the flowers. I think this is true of such bees as fly out to seek new feeding-places; for scout-bees. Another function of scent is to enable the collecting bees to recognise certain flowers to which they are true and to distinguish them from other kinds of flowers. But there is one more function of scent—perhaps the most important. To explain it I must speak about the language of bees.

They have something like a language. That is clear from the following observation: When I want some bees for experiments, I place some sheets of paper smeared with honey on the experiment-table in the open air. Then I have to wait many hours, many days even, until finally a bee discovers the feeding-place. But as soon as one bee has found the honey, very many will appear, perhaps several hundred, within a short time. They all come from the same hive as the first discoverer. The latter must have announced its discovery at home. How is that possible? How could it communicate its discovery?

To clear up the matter two conditions must be fulfilled. First, a hive allowing one to watch all events taking place on the wax combs in the interior of the hive. For this I constructed observation hives in which the wax combs are not arranged one behind the other, but one beside the other, all together forming a large wax comb, the surface of which can be observed through glass windows. Second, every experimental bee must be numbered to enable it to be recognised personally at first sight in the mass of other bees on the wax combs. I succeeded in painting them with coloured spots in five different colours. A white spot on the fore part of the thorax is number 1, a red spot 2, orange 3, yellow 4, green 5. A white spot on the hind part of the thorax is number 6, red 7, orange 8, yellow 9, green zero. Now it is possible to write two-figure numbers. The hundreds we paint on the abdomen. Thus we can number them up to 599. The coloured numbers can be read as easily as written ones, and can be recognised when the bee is in flight, so that at our feeding-place we can see from a considerable distance—here comes No. 17, etc.

Now a bee which has discovered the feeding-place is marked with colour and observed after homing in the observation hive. First, it delivers the honey or sugar water, found and sucked up on our table, to other bees in the hive. Then it begins to dance. On the same spot it turns round and round in a circle with quick, tripping little steps, once to the right, once to the left, very vigorously, often half a minute or a full minute on the same spot. The dance is then often repeated on another spot. It is not possible to give a good description in mere words. The dance finishes just as suddenly as it began, the bee hurries to the hole of the hive and returns to the feeding-place.

The bees on the wax comb around the dancing bee become greatly excited by the dance, they trip behind the dancer, following all its turning movements. They turn their heads to it and keep their feelers as closely as possible to its body, and it is evident that they are highly interested. Suddenly one of the following bees and then another turns away, cleans its wings and antennæ, and leaves the hive. Soon afterwards these new bees appear at the food-place. After homing, they dance also and the more bees there are dancing in the hive, the more appear at the feeding-place. It is clear that the existence of the food is communicated by the dance in the hive. But it is not clear how the bees which have been communicated with can find the feeding-place. How can they know where it is, and where they have to fly?

The simplest assumption would be that when the discoverer returns to the feeding-place the new bees fly behind it. But that is not the case. The new bees do not fly behind our marked discoverer, they appear at the feeding-place quite independently.

I could not understand it, till I made the following experiment: I fed some of the numbered bees of the observation hive at a feeding-place 40 feet to the west of the hive. In the meadow round the hive to the north, south, west and east, I put glass dishes with sugar water and a little honey on the ground. If the dancer bee dancing in the hive reported where the feeding-place was, the new bees would all fly to the west feeding-place. As a matter of fact, a few minutes after the commencement of the dance new bees appeared at the same time at all the little dishes to the north and south, to the west and east. They did not know where the food was. They flew out in all directions and looked for it. When there were no dances in the hive, the little glass dishes in the meadow were not visited by any bee for many days. As soon as there were dances in the hive, the dishes in the neighbourhood were all found within the shortest time.

But not only in the neighbourhood! In further experiments I left the feeding-dish, visited by some numbered bees, at a short distance from the hive. And I put some other dishes farther and farther away in the meadow, observing whether they would be found or not. The farther they were the longer time it took till they were found by the bees sent out by the dancer. In the last experiment they were found after four hours in a meadow a full kilometre from the hive, with hills and woods lying between them. It is clear from a long series of experiments that after the commencement of the dances the bees first seek in the neighbourhood, and then go farther away, and finally search the whole flying district.

So the language of bees seemed to be very simple. But feeding from glass dishes is not natural for bees. If we make the conditions more natural, we get a new riddle at once.

We put the glass dish away, and feed the numbered bees at the same place on flowers, *e.g.* on cyclamen. Into the flowers we drop sugar water to provide plenty of food. The collecting bees dance after homing. New bees fly out seeking—but seeking something definite. In the vicinity we put a larger dish with cyclamen on the ground, and a similar dish with phlox. The new bees are only interested in cyclamen. They take no notice of phlox. Now we change the flowers at the feeding-place and put food in phlox-blossoms. After 5 or 10 minutes the situation at the observation-place changes, the new bees now are not interested in cyclamen, they only alight on phlox and search through the flowers, examining them as if they were convinced there must be food there. Everywhere in neighbouring gardens where phlox plants are we can observe questing bees—a curious sight for everybody aware that bees cannot get honey from phlox blossoms and therefore never visit phlox under normal circumstances. The dancer bee has not only reported that there is food, but also in what kind of flowers it is to be found.

In performing this experiment I succeeded with all kinds of flowers with the exception of flowers without any scent. And so it is not difficult to find out the manner of communication. When the collecting bee alights on the scented flowers to suck up the food, the scent of the flower is taken up by its body-surface and hairs, and when it dances after homing the interested bees following the movements of the dancer bee, and holding their antennæ against its body, perceive the specific scent on its body and know what kind of scent must be sought to find the good feeding-place announced by the dancing bee. That this view is correct can be proved easily. We feed some numbered bees, giving them

sugar water in a glass dish, on a cardboard on which some essential oil has been dropped. Then, in the neighbourhood on the ground, we put some cardboards with drops of various essential oils on them. The bees sent out by our dancer bees are only interested in the scent of the essential oil dropped on the feeding-cardboard, and alight on every place and everything provided with this scent. They take no notice of cardboards provided with other essential oils.

It is thus seen that there is a biological function of flower-scent not known before. The dancing bee can communicate a message about all kinds of scented flowers by means of the scent adhering to its body.

But the language of bees is still more perfect than has been shown up to now. A little variation of our experiment makes this clear. At the feeding-place we put sugar water in the glass dish, and we renew all sugar water taken away by the collecting bees. There is plenty of food. The collecting bees dance after homing, and new bees continually come out, and more and more discover the feeding-place. Now we remove the full glass dish and we put in its place a glass dish provided with some sheets of filter-paper moistened from beneath with a little sugar water by means of a syringe. Now there is a scarcity of food. It is troublesome to suck it up, and takes a long time. Now the bees do not dance after homing. They deliver the food to other bees and return to the feeding-place, they continue to collect the food no less industriously, but they do not dance, and so they do not attract new worker bees to their feeding-place. Just the same is true of flower-visiting bees. They only dance if they find plenty of food. As soon as the flowers are visited by so many bees that all nectar produced by the flowers can be easily collected and taken away, there is no longer plenty of food, the dances stop, and no more worker bees are attracted. This makes it possible that there is always a correct proportion between the number of collecting bees and the quantity of food offered by a certain kind of flowers.

But one more thing still—the dances depend not only on the quantity of food but also on its sweetness. If we feed the bees with sugar water of a very high concentration the dances are very vigorous. If the concentration is diminished, the dances are continued, but less vigorously. If the concentration is still further diminished to a certain point, the collection of food is still continued, but there are no dances in the hive, although there is plenty of food. In natural conditions this is very important. For when various kinds of flowers with different concentrations of nectar

begin to bloom at the same time, and are discovered by scout bees belonging to the same hive, the bees discovering the flowers with the best nectar dance most vigorously, and attract the largest number of worker bees for the best flowers. That is the rôle of the sense of taste in the language of bees.

But there is a word in the bee language not yet mentioned. The bees have a scent organ on their abdomen located in a pocket of skin containing glands. Usually the scent organ is closed and cannot give out scent. But bees which have discovered a good feeding-place put out the scent organ on returning to the place, and thus they give out a scent that is very attractive to other bees. It can be concluded from special experiments that the scent of this scent organ is much more intensive for bees than for us. It tells the questing bees with special emphasis where the good place is, as soon as they are in the vicinity, and attracts them from quite a considerable distance.

It may be that some of my statements seem to be a little hypothetical. But all the results I have mentioned have been obtained from long series of experiments. To deal more thoroughly with the experimental methods here is impossible.

To sum up : If a new kind of flower begins to bloom in a certain region, it is discovered after some time by scout bees. The first bees find the flowers full of nectar. They find plenty of food and after homing they report the discovery by dancing, and in addition indicate the species of flowers by means of the scent adhering to their bodies. The bees communicated with fly out and look for the flowers with this specific scent. Flying out in all directions, they find out in the shortest time the plant which has commenced to bloom, wherever it is in the entire flying district. Where there are already collecting bees, the scent of the scent organ makes it easier for fresh questing bees to find the good feeding-place. When the number of bees has become sufficient to collect the amount of nectar in these flowers, the flowers are no longer full of nectar, the nectar becomes scarce, there is no more dancing and the number of bees does not increase. If different plants begin to bloom at the same time, the flowers with the sweetest nectar cause the most vigorous dancing and, incited by the scent adhering to the body of the dancer bee, the largest number of bees fly to the best feeding-plants.

RADIOELEMENTS AS INDICATORS IN CHEMICAL AND BIOLOGICAL RESEARCH

BY G. HEVESY AND F. A. PANETH

*Institute of Theoretical Physics, Copenhagen, and Imperial College of Science and Technology,
London*

RADIOACTIVITY is generally regarded as somewhat remote from the interest of practical chemists, who are not specially attracted by descriptions of what is going on in the interior of an atomic nucleus, nor thrilled by the news that we can now produce invisible and infinitesimal quantities of gold, provided of course that we are allowed to invest expensively in platinum as our raw material. In this essay, however, we are not concerned with radioactivity in its proper sense, but only with the use of radioelements as tools for the solution of problems which have nothing whatever to do with radioactivity.

Owing to the extreme sensitivity of electrometric methods it is possible to detect radioelements in much smaller concentrations than any other chemical substances. As a rule for quantitative determinations at least 10^{-6} gm. are necessary, even if so-called micro-chemical methods be applied. It is true that spectroscopy can often not only detect, but even measure, much smaller amounts, down perhaps to 10^{-9} or 10^{-10} gm. But only the methods of radioactivity are able exactly to determine quantities of matter of the order of, say, 10^{-17} gm.; if an element is strongly radioactive, we can easily study its chemical behaviour qualitatively and quantitatively even though it be completely invisible.

As most of the radioelements are isotopic with ordinary elements in many investigations it is possible to substitute a radioelement for its inactive isotope. In other cases it will be found advantageous to mix a certain amount of the radioelement with a sample of the inactive isotope, to which a definite radioactivity is thereby imparted; owing to the inseparability of isotopes this radioactivity remains as a characteristic property of such an "indicated" sample, whatever the chemical or physical reactions carried out with it. By choosing an appropriate ratio between

the quantities of radioelement and inactive element in the sample, it is possible to cover the entire range of mixtures from those detectable only by means of the electroscope to those containing easily weighable amounts of material.

Before giving examples of practical applications of radioelements as indicators, a few words must be said about technique. How do we obtain the radioactive indicators, and how do we measure their quantity?

If we wish to use *natural radioelements* we must confine ourselves to the last two rows of the periodic system, since only in the range from thallium to uranium are the 40 or so natural radioelements, belonging to the uranium, thorium, or actinium series, to be found. In this region, however, there are frequently several radioelements isotopic with one and the same stable, or slowly disintegrating, element. Now in selecting a radioelement suitable as an indicator it is advisable in general to pick one that can be detected in quantities as small as possible; we must bear in mind, however, that the half-value period (T) varies in inverse proportion to the strength of the radiation, and that an element measurable in tiny amounts necessarily possesses a short half-value period. It follows therefore that we cannot draw upon all the radioelements for our present purpose. Only such as are included in the table on page 40 have any practical application, owing to the favourable length of their decay periods; those most frequently to be recommended are printed in italics.

In addition to the natural radioelements hitherto considered, the recently discovered *artificially produced radioelements* can fortunately also be used as indicators. We know that the bombardment of certain of the elements by α -particles results in the production of radioactive substances which emit positrons on disintegration; and in the bombardment of almost all the elements by neutrons new types of atoms are formed, which are transformed by the emission of electrons. Provided that these artificial radioelements are produced in quantity sufficient to be easily detectable, and their life-period reckoned in minutes or more, they are also adapted for use as radioactive indicators. Although the discovery of the artificial radioelements is of quite recent date, a significant number of investigations have already been made on these lines, and there can be no doubt that in future the artificial radioelements will surpass the natural radioelements in their importance as indicators; for in the study of practically all the elements in the periodic classification they place at our disposal the corresponding active isotopes, including those of carbon, phosphorus, sodium, and

RADIOACTIVE INDICATORS

Atomic Number.	Element.	Indicator.
81	Thallium	Radium C'' Thorium C'' Actinium C''
82	Lead	Radium B Radium D Thorium B Actinium B
83	Bismuth	Radium C Radium E Thorium C Actinium C
84	Polonium	Radium A
86	Radon	Thoron Actinon
88	Radium	Thorium X Actinium X
89	Actinium	Mesothorium 2
90	Thorium	Ionium Radiothorium Radioactinium Uranium X ₁
91	Protactinium	Uranium X ₂

calcium, which are of special importance in biological experiments. Sometimes it is even possible to produce radioactivity directly in the chemical compound of the element to be investigated.

As to the measurement of radioactivity, an electroscope will give a sufficiently accurate determination in most of the natural elements, but for ascertainment of the much weaker activity of artificial radioelements a more elaborate apparatus, such as Geiger-Müller tube, connected with an amplifying system, is requisite. Nowadays almost any wireless shop can supply the material.

In parenthesis it may be mentioned that in cases where inactive isotopes are readily accessible, they can be used as indicators in fundamentally the same manner, though other methods of measurements must be applied. For instance, instead of using electro-

metric measurements it is necessary to determine density or thermal conductivity, and so forth. Such experiments have been carried out with the heavy isotope of hydrogen ^3D and the oxygen isotope ^{17}O ; but further discussion of them is outside the scope of this article.

The applications of "radioelements as indicators" fall mainly into three groups; with their aid:

- (A) We can study the behaviour of minute quantities of a radioelement, or indicated element, down to invisible and unweighable amounts.
- (B) We can determine very small fractions of an indicated substance which has been separated from the main part by solution, diffusion, etc.
- (C) By mixing only a fraction of a stable element with its radioactive isotope we can differentiate this fraction from the rest of the element, and then *study the exchange of atoms of identical chemical properties*. It is especially this use of indicated atoms which opens the door to otherwise insoluble problems.

A. THE STUDY OF MINUTE QUANTITIES OF AN ELEMENT

A problem frequently experienced in analytical chemistry is the distribution of traces of an element between precipitate and solution; minute amounts of many elements are included either by co-precipitation or by adsorption in the crystals of a precipitate or, conversely, remain dissolved when the bulk of the element is removed. In the case of radioelements or indicated elements such an imponderable quantity can be determined without the slightest difficulty. Studies of this type have shown that methods of chemical separation, which are reliable for normal weights of matter handled in an analytical laboratory, fail in the collection of small amounts.

For example, if we want to determine the lead content of ordinary rocks or meteorites, which is only of the order of a thousandth of a per cent., we find its quantitative separation practically impossible; in this case the application of radium D as an indicator has proved to be very useful. For this purpose a known amount of radium D was added to the solution of the material and by electrolysis this was deposited anodically as RaDO_2 , together with the contained lead. Thus, if in this process only 80 per cent. of the amount of RaD originally added were regained by electrolysis, it follows that the yield of the lead analysis was likewise only to the extent of 80 per cent., and consequently the mass of

the deposit must be increased by 20 per cent. in order to obtain a quantitative value for the lead content of the rock.

In this simple example the radioelement RaD serves directly as indicator of the element to be estimated, *i.e.* lead. But the range of application of the radioactive method in analytical chemistry can be considerably extended if the element lead, activated by the radioelement ThB or RaD, is in its turn only the reagent for the substance (*e.g.* ammonia) in which we are interested. This method of "radiometric microanalysis" has rendered it possible, for instance, to carry out a determination of the nitrogen content of organic substances down to the order of magnitude of some ten-thousandths of a milligram.

B. THE DETERMINATION OF VERY SMALL FRACTIONS OF AN INDICATED SUBSTANCE

The solubility of lead chromate at room temperature is too small to be determined with accuracy by gravimetric methods; but with the help of a radioactive indicator we can measure it as readily as we can perform a simple weighing operation. For this purpose we add a definite quantity of ThB to a known amount of a soluble lead salt. The radioactivity of this substance can be measured in terms of any arbitrary unit such as the number of scale divisions per minute obtained with the electroscope used. Thus if 10,000 such units of ThB have been thoroughly mixed with 10 mg. of lead, it is clear that one unit of the ThB will then necessarily always indicate the presence of 0.001 mg. lead. Now we can prepare the lead chromate from the artificially activated lead by the usual chemical methods. If we have kept the saturated solution of this compound sufficiently long in a thermostat at the desired temperature, we can determine its concentration by evaporating to dryness a few c.c. of the solution, and measuring with the electroscope the activity of the almost invisible residue. A special advantage of the method is that the presence of foreign ions interferes in no way with the measurements as, of course, only the radioactive substance influences the electroscope.

Another problem in which a very small quantity of the initial amount of an element had to be detected was encountered in the search for the hydride of bismuth, the analogue of arsine and stibine. As a result of many fruitless attempts to prepare it, the conclusion was reached that, supposing it could be prepared at all, this compound would only be obtainable in amounts corresponding to vanishingly small fractions of the initial quantities of material used, and that it would thus readily escape detection by

the usual chemical methods. But the sensitivity of radioactive measurements can be graded down so far as to encompass both qualitatively and quantitatively even the ten-millionth part of the initial amount of the substance. This enormous extension of the range of measurement is necessary if we are to study the condensation and re-volatilisation of bismuth hydride; but the fact of its existence can be shown by relatively simple means. When magnesium filings are coated with the bismuth isotopes ThC or RaC and dissolved in dilute hydrochloric acid, the volatile hydrides of these radioelements are evolved, and can be condensed at the temperature of liquid air, or decomposed in a hot glass tube and measured. By means of the radioactive method just described it was possible to accumulate experience as to the best mode of preparation and the degree of stability of bismuth hydride; and it was but a short step to the long-sought goal of preparing this compound also from inactive bismuth by similarly dissolving a magnesium-bismuth alloy in hydrochloric acid. It may be mentioned that the quantity of bismuth with which the existence of this volatile compound was first recognised amounted to only 10^{-18} g.

Technical investigations can also benefit from this application of radioactive indicators. It has been found possible to determine quantitatively with speed and accuracy the different permeabilities to air of almost completely airtight gummed material (gas-mask fabrics) by using air containing traces of radon.

In the treatment of syphilis, by making use of Radium E as indicator, the retention of bismuth in the organism was investigated in detail. For a long time after treatment a considerable amount of the metal remains in the body, maintaining an anti-syphilitic effect; the important matter was to gain information as to the rate at which different bismuth compounds are resorbed after injection. A further investigation concerned the retention of lead (indicator: ThB or RaD) and of thorium (indicator: ThX or Io), both in human and animal bodies; extended to the behaviour of tumours, it proved that cancerous tissues retained appreciably larger amounts of bismuth than the corresponding healthy tissue.

While in the examples quoted the problem was to determine fractions of the original substance, a biological experiment may be mentioned where the total amount of a substance was unknown, and could be inferred from an activity measurement of a fractional part. In the case of rabbits the quantity of blood in living animals was determined as follows. A small quantity of defibrinated blood of the animal was mixed with a weakly alkaline solution of ThB,

and a precise amount of this injected into one of its veins. This active blood very quickly mixed with the blood of the entire circulatory system, and so uniformly that even after a few minutes the activity of blood taken from an artery permitted calculation of the volume of fluid throughout which the injected mixture of blood and ThB had been distributed, or, in other words, the total quantity of blood in the animal's circulation.

C. THE EXCHANGE OF ATOMS OF IDENTICAL CHEMICAL PROPERTIES

The interchange of atoms and molecules within a homogeneous substance can be followed *only* by means of isotopic indicators. The simplest example of such a kinetic problem is presented by the addition of an activated solution of $\text{Pb}(\text{NO}_3)_2$ to an inactive solution of PbCl_2 of equivalent strength. By crystallising from this mixture a sample of lead chloride, we can determine whether it contains not only those lead atoms which were linked with chlorine before the mixing, but also lead atoms originally combined in the form of nitrate. As we should expect, according to the theory of electrolytic dissociation, the result of such a determination demonstrates that the lead atoms in the crystallised lead chloride were derived in equal numbers from the two initial solutions. On the other hand, if, let us say, activated lead nitrate and inactive tetraphenyl-lead, or another compound in which the lead atom is linked with carbon in a non-ionisable form, be simultaneously dissolved and then separated by crystallisation, we are unable to detect any interchange of the lead atoms between the lead nitrate and the organic compound of lead.

In an analogous manner it has been possible to show that the charges of di-valent and tetra-valent lead ions are interchanged with the greatest of ease. After the discovery of artificial radioactivity it was also feasible to establish the same phenomenon with manganese ions of different valency, and to examine also the firmness of binding of iodine, bromine, etc., in organic compounds, as well as to study the mechanism of important reactions in organic chemistry. For instance, in the case of a molecule containing iodine, it was possible, by the use of iodine activated artificially, to give an affirmative answer to the question as to whether the racemisation of an optically active compound is preceded by a substitution.

The interchange between the solid and liquid phases, as between metal and ion, or between a salt and its saturated solution, is more difficult to picture, and for this reason even more important to investigate than the positional interchange in solutions. These

processes, as functions of time, can be readily followed by means of radioactive indicators; and such investigations can be made the basis of a method of measuring the surface area of powders, which is of importance in experiments on adsorption. This method is based on the fact that when a radioelement is added to a saturated solution of the isotopic adsorbent, in the form of powder, it must distribute itself uniformly in a very short time between the molecules of the dissolved part of the adsorbent and the molecules of the outermost layer of the undissolved part of the powder. From the diminution of the radioactivity of the solution in this way we can easily calculate the dimensions of the surface of the powder. The surface areas of lead sulphate, lead sulphide, bismuth phosphate, and of many other compounds have been measured in such a manner; and with the aid of the data so obtained it has been possible to prove that, for all these adsorbents, the limit of adsorption is reached before the adsorbed substance has formed a coherent layer even one molecule thick on the surface of the adsorbent.

Closely related is the method which made possible, by the use of radioelements, an experimental investigation of the process of "self-diffusion." Here we are concerned with the fact predicted by the kinetic theory of matter that the atoms (or molecules) of a homogeneous gas or of a liquid move amongst themselves according to the same laws which govern the diffusion of one element into another. But since in the process of self-diffusion the objective properties of the element investigated remain entirely unchanged, this process could previously be carried out only as a conceptual experiment. Not until the introduction of radioactive indicators was it possible to open up to observational study the phenomenon of self-diffusion. In performing the experiment, a lead cylinder was fused into a hard glass tube, three-quarters of the length of the cylinder consisting of ordinary lead and the remaining quarter of activated lead. For experiments of short duration ThB was used as indicator, whereas for those of long duration RaD was chosen. By carefully melting the lead in the tube and maintaining it at liquefying temperature for several days the indicated active atoms of lead were intermingled with the other lead atoms by diffusion; it was possible after solidification to investigate the distribution of the activity established in the column of lead during the experiment, and the constant of self-diffusion in liquid lead could be calculated by the usual methods. By application of specially sensitive methods it was also possible to measure the coefficient of self-diffusion in solid lead.

In a similar way we can follow the change in position of the lead ions in heated crystalline lead chloride, and hence draw conclusions about the processes of diffusion and conduction of electricity in crystals.

After the discovery of artificial radioactivity it was possible to examine the circulation of phosphorus in human or animal systems. The active form of phosphorus was produced from sulphur, and the atoms of phosphorus in food could be indicated by the addition to them of sodium phosphate of known activity. In this manner it was established, for instance, that in the course of 5 days, 22 per cent. of the phosphorus atoms in a man's food are evacuated by the kidneys and 16 per cent. by the bowels, whereas when the phosphorus atoms are introduced directly into the bloodstream the corresponding proportions eliminated are respectively 20.5 per cent. and 2.5 per cent. in the same time. The remainder of the phosphorus atoms enter into the structure of various organs, and above all into the bones, whence they are sooner or later displaced by the arrival of fresh phosphorus atoms. It was possible to measure the rates at which the resorbed inorganic phosphate ions enter into the blood corpuscles and at which the various organic phosphorus compounds develop in them, as well as to determine the distribution of the phosphorus atoms taken up in the system between individual bones, muscles, liver, kidneys, teeth, and so on. The study of the behaviour of the phosphorus in the brain was of special interest. If some ten hours after administration of radioactive sodium phosphate to rats or other animals the phosphatides of the brain are extracted, they are found to contain radioactive phosphorus atoms. Now we know that phosphorus atoms present in a phosphatide molecule take no part in simple exchange processes; therefore the radioactive phosphorus atoms can only have entered these molecules during their synthesis. Hence, from the presence of radioactive phosphatides in the brain tissue of fully grown animals after the intake of radioactive sodium phosphate, we can conclude that these tissues, contrary to general assumption, are constantly regenerated; presumably the lecithin molecule, under enzyme action, is broken down and rebuilt.

Analogous experiments undertaken with maize and sunflowers showed that most of the phosphorus atoms are found in the leaves, and that they are mobile. Investigation revealed that an individual phosphorus atom which is to-day situated in one leaf in the course of a few days will very probably be found in another leaf, while in seeds no exchange takes place between the phosphorus atoms of the germ and of the endosperm.

In concluding, it may perhaps be emphasised that experiments with radioactive indicators by no means involve heavy costs. As will be seen from the above examples, many of the experiments have been carried out with thorium B or thorium C as indicators. As both of these substances are themselves quite short-lived ($T_{\text{ThB}} = 10.6$ hours; $T_{\text{ThC}} = 60.8$ minutes), the quantities of radioactive substances used in the individual experiments have therefore practically no monetary value; for these amounts are freshly obtained before each experiment from the parent substance radiothorium, which itself remains completely unchanged and only decays with a half-value period $T = 1.90$ years. Since a quantity of radiothorium, whose α -radiation is equivalent to that of 1 mg. radium, supplies an adequate amount of ThB and ThC for almost all indicator experiments, and this quantity is for the most part always regenerated 24 hours after removal of the preparation from the radiothorium, it is possible with 1 mg. radiothorium to perform an indicator experiment either with ThB or with ThC daily throughout a period of several years. At the present time 1 mg. radiothorium costs about £8. In many experiments distinctly smaller amounts of radiothorium will suffice; on the other hand of course there are also experiments in which greater activities are desirable, just as occasionally it is impossible to avoid using as indicators radioelements of long life such as RaD and RaE, which are more difficult to obtain.

The acquisition of artificial radioelements as indicators also does not necessarily involve large monetary expenditure, especially when, as is often the case, radon can be obtained from hospitals and similar institutions. A small glass tube filled as full as possible with very finely grained beryllium powder and with radon constitutes a source of neutrons which can be used for several days for the production of artificial radioelements. Quantities of about 50 millicuries of radon suffice for many experiments; for others, however, hundreds of millicuries of radon are necessary; still stronger active preparations can be obtained by bombardment with deuterons which have been accelerated say in a cyclotron. When a source of neutrons is required for continuous use it is of course desirable to mix a salt of radium instead of radon with beryllium powder. The cost can frequently be reduced by hiring radium for a specified period instead of buying it.

References to the original papers can be found in the books *Radioelements as Indicators* by F. A. Paneth (McGraw-Hill Book

Co., New York, 1928), and *Applied Radiochemistry* by O. Hahn (Cornell University Press, Ithaca, N.Y.; Oxford University Press, London, 1936).

The authors are indebted to the Oxford University Press for their kind permission to use freely in this article a chapter of the second English edition of their *Radioactivity*, now in print, as well as the manuscript of a booklet, on practical work with isotopes as indicators, which they hope soon to publish.

EARTHQUAKE-SWARMS IN JAPAN

By CHARLES DAVISON, Sc.D., F.G.S.

IN addition to their destructive shocks, the Japanese islands possess a class of earthquakes that seem to be rare or non-existent in other seismic countries. They have been called "earthquake swarms" by Japanese writers, and consist of large numbers of slight shocks, sometimes one or two hundred a day, that may or may not cul-

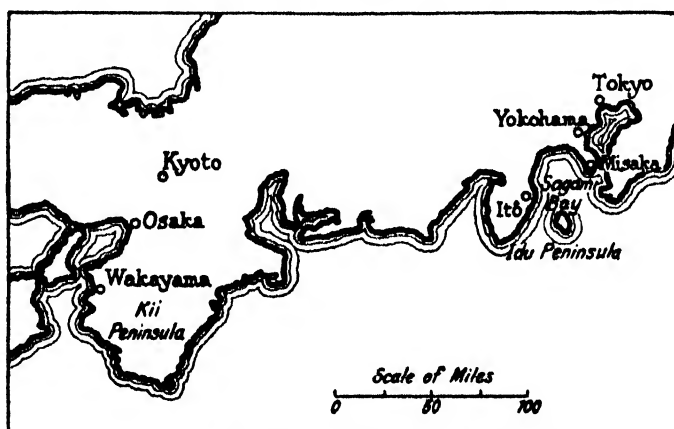


FIG. 1.—Map of the southern coast of Japan.

minate in a great earthquake. During the last twenty years there have been two such series, one in the Nagusa district on the west coast of the Kii peninsula (Fig. 1), that has not yet led up to an earthquake of unusual strength, the other near Itô in the Idu peninsula, followed before the close of the year by the destructive Idu earthquake in an adjoining district.

THE NAGUSA EARTHQUAKE-SWARM

The area within which the shocks were felt is represented in Fig. 2. It lies on the west side of the Kii peninsula that runs southward from near the cities of Osaka and Kyoto. During the

fourteen years 1906-19, the annual number of earthquakes recorded at the station of Wakayama ranged from 3 in 1918 to 25 in 1911, with an average of 14. Then, during the eight years 1920-27, the numbers rose to 105, 154, 100, 299, 195, 210, 148 and 142.

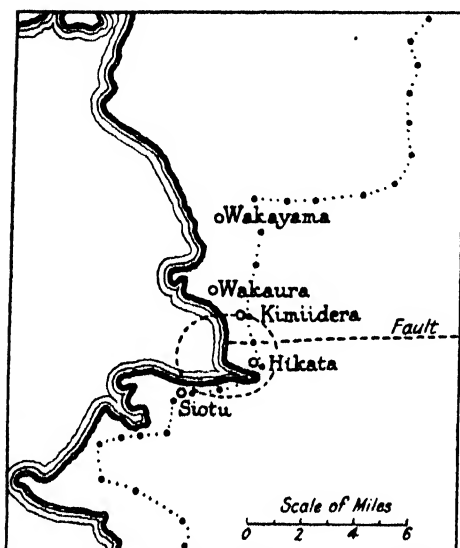


FIG. 2.—Map of the Nagasa earthquakes area.

In 1928, a network of seven stations was formed round the area, but, when the smallness of the area was recognised, two of them were abandoned, the five left being Wakaura, Hikata, Siotu, Tanabe and Tomioka.

The total number of earthquakes was very great, though the majority of them were so slight that, from May 1929 to July 1931, only 91 were registered with such precision at three or more stations that their epicentres could be determined. During the

interval mentioned (27 months), 931 earthquakes were recorded at Hikata, 729 at Wakaura and 605 at Siotu. The number at Kimiidera would probably in the same time have approached 1,500, for, in ten months (May 1929 to February 1930), 551 were recorded.

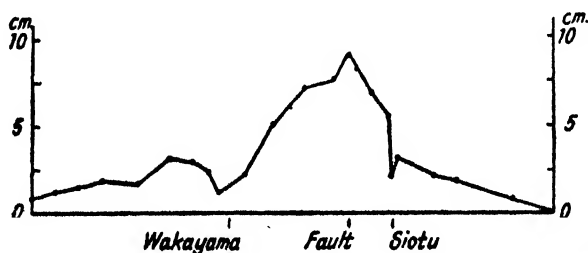


FIG. 3.—Changes of level in the Nagasa earthquakes area.

The epicentres of the 91 earthquakes lie for the most part in the area bounded by the broken line in Fig. 2. Though this is less than one-tenth of the whole number, the studies made by Professor Imamura and his colleagues render it probable

that the remainder belong to the same centres, so that the origins of the earthquake-swarm must be under the sea to the west of Wakaura and Hikata.

Few of the areas disturbed by these shocks had a diameter of more than 25 miles, the strongest of all were just capable of making cracks in plaster walls or overturning unstable objects, and, though very rarely, of throwing down stone fencings.

The records of the meteorological station of Wakayama show on the whole a gradual decline in frequency from 1923, and a similar decline is apparent in those at Wakaura, where the average monthly number during successive three months from May 1929 to July 1931 were 42, 33, 25, 38, 17, 17, 25, 26 and 21.

One of the most interesting results connected with this earthquake-swarm is that of the change of land-level in the district. The dates of the two lines of levels run along the west coast of the Kii peninsula are not given by Imamura. One of them, however, was clearly after the swarm attained its height and the other thirty years before. The resulting changes of level are shown in Fig. 3, and Imamura remarks that there is good reason for believing that the greater part took place after 1920. It will be seen that the more marked changes are local, and that a crust-block, $6\frac{1}{2}$ miles in diameter, with its north end near Wakayama and its south end near Siotu, has bulged upward. The greatest uplift of about 9 cm. occurred at a fault, represented by a broken line in Fig. 2, and it is along or near this fault that most of the known epicentres lie. It would seem that the dome formation is due to lateral pressure acting in opposite directions on the block and that the swarm of feeble shocks is the result of stresses now growing on the floor of the Pacific Ocean off the Kii peninsula, in a region that has been the seat of some of the most devastating of Japanese earthquakes.

THE ITÔ EARTHQUAKE-SWARMS

Itô is a watering-place on the east coast of the Idu peninsula and facing Sagami Bay, beneath which lay the centre of the great Kwanto earthquake of 1923. During 1930 it was visited by swarms of earthquakes of much greater frequency and intensity than those of Nagusa. The positions of the foci were determined by Mr. N. Nasu and his colleagues, the tilting of the ground was studied by Messrs. M. Ishimoto and R. Takahasi, while the changes of level of the land were exhaustively measured by the Military Land Survey and interpreted by Mr. C. Tsuboi. The Itô district is shown in Fig. 4.

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A number of observers were sent from the Earthquake Research Institute and the Seismological Institute of the Imperial University of Tokyo to make detailed studies in the district. A network of five stations was completed by March 10. Two-component portable tromometers were erected at Itô and Aziro and single-component tromometers at Hasima, Usami and Kawana (Fig. 4). In addition, two tiltmeters were installed, one at Itô on March 12 and the other

at Kawana on March 19, both in caves excavated in the mass of volcanic scoriae. Between 1930 and 1936, no fewer than five lines of precise levelings were carried out along the east coast of the Idu peninsula by the Military Land Survey.

The shocks were recorded throughout at Misaki, a station about 30 miles north-east of Itô, and the figures and curves given below include all shocks with an amplitude exceeding one micron at Misaki, that is, shocks that would as a rule be felt by the unaided senses at Itô. Diagrams representing the daily numbers of such shocks are given by Imamura and his colleagues for the interval

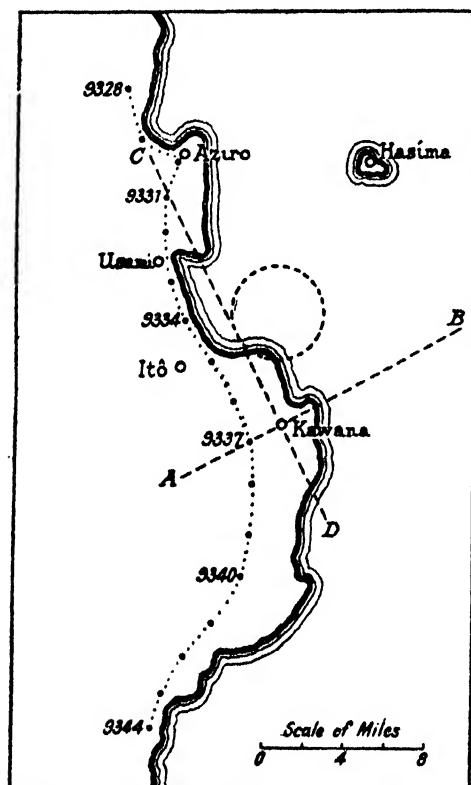


FIG. 4.—Map of the Itô earthquakes area.

February 13 to April 7, and by Ishimoto and Takahasi for that from February 13 to May 31. In neither case are the daily numbers entered, but they may be read from the diagrams with a close approach to accuracy.

The first swarm began on February 13, reached its maximum daily number of 209 on March 9, and declined, with many oscillations, until it may be said to have ended on April 12, the total number of shocks in this swarm being 3,751 and the average daily number 64 (Fig. 5). From April 13 to May 7 inclusive, the daily

numbers ranged from 1 to 8, the average being 3.6. On May 9, the number suddenly rose, from 6 on the preceding day, to 126, reached its maximum daily number of 165 on May 10, and then declined irregularly until May 22 with 20 shocks, after which, until the end of the month, there were only 6 shocks. The total number of shocks in the second swarm from May 8 to 22 was 1,100 and

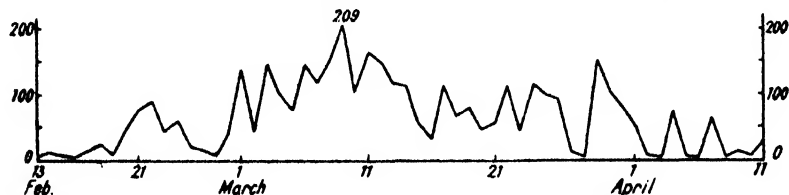


FIG. 5.—Curve of frequency of Itô earthquakes.
First series (Feb. 13-April 11).

the average daily number 73 (Fig. 6). Thus, altogether from February 13 to May 31 there were 4,947 shocks.

Although the great majority of these shocks were very slight, indeed only just sensible, a few of them were strong enough to overturn gravestones and to crack plaster walls. The strongest were those of March 9 and 22. The amplitude at Itô of the former was 4 mm. and that of the latter 12 mm. or nearly half an inch.

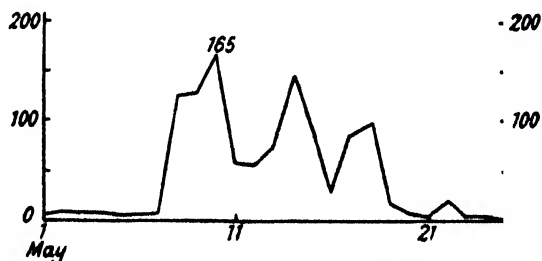


FIG. 6.—Curve of frequency of Itô earthquakes.
Second series (May 1-25).

A strong-motion seismograph of the Central Meteorological Observatory erected on a sandy beach at Itô, midway between the Itô seismological station and the epicentre, recorded on March 22 a movement with an amplitude of 50 mm. or about 2 in.

The positions of the epicentres and the depths of the foci were determined by Nasu from the records at three or more stations. For the first series (to the end of March), he found that the epicentres were as a rule clustered within a small circle (represented by the broken line in Fig. 4), the diameter of which is about $2\frac{1}{2}$

miles. As will be seen, this small area lies within the inlet of Itô. Most of the few exceptions lie along or near the line AB, running from a point close to Kawana in the north-north-east direction.

Nasu illustrated the distribution of the earthquake-foci by projecting them on two vertical planes; one passing through the line AB (Fig. 7a), the other through the perpendicular line CD (Fig. 7b). The projections of the foci lie between the broken lines in the diagrams, showing that the foci were confined to a narrow conical region, its base being the circular area of about $1\frac{1}{2}$ miles radius and its vertex at a depth of about 6 miles. The foci were densely packed near the surface and thinned out gradually downwards. For the second series in May, some of the foci lay a little way outside the cone to the east.

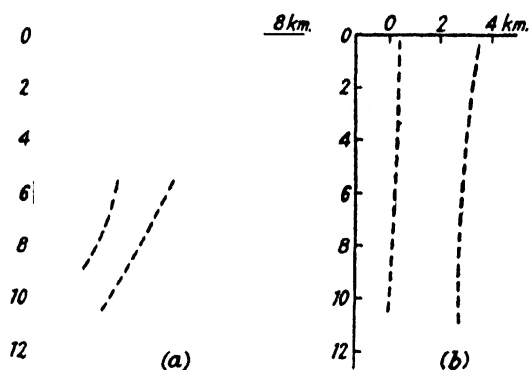


FIG. 7.—Itô earthquakes: projections of foci.

From a series of precise levellings, the line AB was found to represent the boundary between two crust-blocks. It is worthy of notice that the east end of the line AB lies over the 80-metre depression formed in the bed of Sagami Bay during the earthquake of 1923, and that, if produced, it cuts at right angles the two great faults in the sea-bed and also, still farther, passes over the trough of 100 to 180 metres in depth, formed at the same time.

The records of the tiltmeters at Itô and Kawana have added to our knowledge of the movements of the crust-blocks. The curves representing the variations of inclination show that strong earthquakes occur at the times when the tilts are very rapid and simple, and slight earthquakes when they are complicated. At Itô, the principal directions in which the crust-block was tilted are towards the west and south; at Kawana mainly towards the west.

Imamura and his colleagues compiled a table of the hourly

frequency of the shocks and compared the variations shown by it with those of other natural phenomena, especially with those of the sea-level. The shocks came as a rule in clusters, as many as 80 sometimes in an hour, the beginning of the clusters in the early stages coinciding with low tide and their ends towards high tide. Towards the close of March, however, the connection became less marked. Kunitomi, adopting a slightly different method, counted the numbers of shocks in successive hours, including low tide and in five hourly intervals on either side, the numbers from the fifth hour before to the fifth hour after being :

27, 21, 33, 34, 64, 80, 64, 41, 55, 39, 42,

a series of numbers that shows very clearly that the earthquakes of the swarm were more frequent at low tide, and implies that the crust-movements causing the shocks were upwards as a rule.

It would have been interesting from this point of view to determine the maximum epoch of the lunar period of 14.8 days. Unfortunately, the times of the shocks have never, so far as I know, been published with the exception of 20 of the stronger earthquakes from March 4 to May 17. These, though too small in number for good results, give the epoch at the times of new and full moon (amplitude 0.63), showing again that the crust-movements were mainly upwards, a result of some interest in connection with the remarkable changes of elevation now to be described.

Few districts have been so frequently re-levelled as that of the Itô earthquakes. The line of bench-marks is represented by the dotted line in Fig. 4, the bench-marks by larger dots. The dates of successive surveys since the earthquake-swarm began are :

- (I) March 15–April 14, 1930.
- (II) November 9–December 3, 1930.
- (III) December 19, 1930–January 3, 1931.
- (IV) December 25, 1932–March 16, 1933.
- (V) January–March 1936.

The last survey before 1930 (denoted 0 in Fig. 8) was carried out in 1923–24, after the Kwanto earthquake of September 1, 1923. For the first four intervals from 1923, the bench-mark 9328 was supposed to be unaltered in level; for the last interval V–IV that numbered 50 (lying to the north of the map in Fig. 4). The changes of elevation that occurred in the first four intervals have been described by Mr. C. Tsuboi in an admirable series of memoirs. The changes in all five intervals (referred to B.M. 9328 as zero) are represented in Fig. 8.

The most interesting changes are those of the last four intervals,

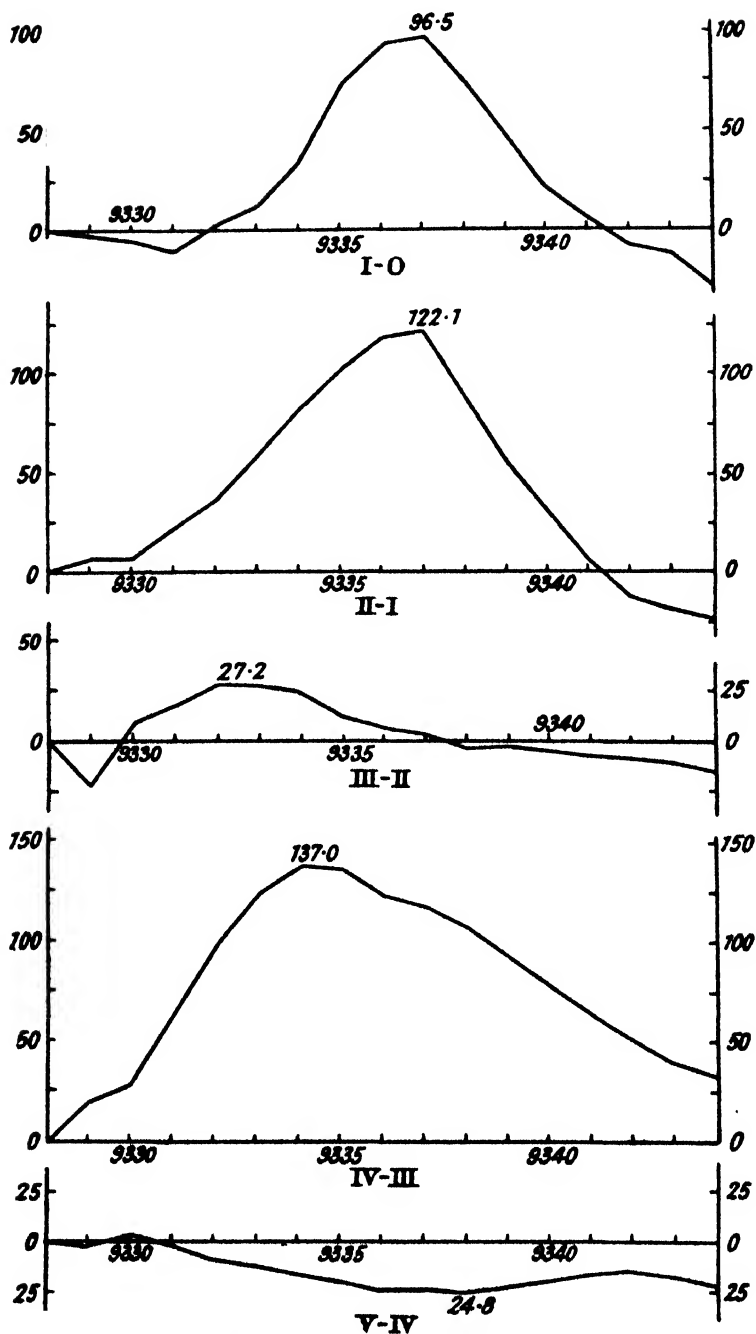


FIG. 8.—Changes of level in the Itô earthquakes area.

that is, since the earthquake-swarm began. The Idu earthquake of November 26, 1930, it may be noted, occurred during the second interval, but produced no effect on the level of the east-coast route. In the first two of the intervals, the greatest uplifts, of 96.5 and 122.1 mm., occurred at B.M. 9337, a short distance to the south of Itô; in the third, it was 27.2 mm. at B.M. 9333, near the north end of Itô Bay; in the fourth, 137.0 mm. at B.M. 9334; and, in the last, 17.0 mm. still farther to the north or 1.1 mm. (with reference to B.M. 9328) at B.M. 9330 near the south coast of Atami Bay. Two other points are also worthy of notice: (1) The region of greatest uplift in the first two intervals became one of depression in the last, B.M. 9337 being lowered 8.5 mm. with respect to B.M. 9328, and 24.4 mm. with respect to B.M. 50; and (2) since 1930, the district has been almost seismically inactive, and yet the crustal deformation of the district has continued, though at a less rate than in 1930.

REFERENCES

1. Earthquake Research Institute, "Relative Vertical Displacements of Bench-marks along the Line of Levels from Yugawara to Zyotomura, on the East Coast of the Idu Peninsula," *Earthq. Res. Inst. Bull.*, **14**, 1936, 486-8.
2. A. Imamura, T. Kodaira and H. Imamura, "The Earthquake Swarms of Nagusa and Vicinity," *Earthq. Res. Inst. Bull.*, **10**, 1932, 636-48.
3. A. Imamura, N. Nasu, F. Kishinouye and C. Yasuda, "On the Recent Itô Earthquakes," *Tokyo Imp. Acad. Proc.*, **6**, 1930, 190-3.
4. M. Ishimoto and R. Takahasi, "Séismes d'Itô et l'observation sur les variations de l'inclinaison de la surface terrestre," *Earthq. Res. Inst. Bull.*, **8**, 1930, 427-58.
5. S. I. Kunitomi, "Note on the North Idu Earthquake of 1930," *Tokyo Geoph. Mag.*, **4**, 1931, 73-102.
6. N. Nasu, F. Kishinouye and T. Kodaira, "Recent Seismic Activities in the Idu Peninsula," *Earthq. Res. Inst. Bull.*, **9**, 1931, 22-35.
7. C. Tsuboi, "A Note on the Results of the Repeated Precise Levellings across the Itô Seismic Region," *Tokyo Imp. Acad. Proc.*, **7**, 1931, 153-4.
8. C. Tsuboi, "A Note on the Repeated Precise Levellings across the Itô Earthquake Area," *Earthq. Res. Inst. Bull.*, **9**, 1931, 151-8.
9. C. Tsuboi, "Investigations on the Deformation of the Earth's Crust by Precise Geodetic Means," *Japan. Journ. Astr. Geoph.*, **10**, 1933, 93-248 (Itô district, pp. 99-107).
10. C. Tsuboi, "Vertical Crustal Displacement in the Seismic Region of Itô, on the East Coast of the Idu Peninsula," *Earthq. Res. Inst. Bull.*, **11**, 1933, 488-99.

THE RELATION OF BORON TO PLANT GROWTH

By R. W. G. DENNIS, Ph.D., B.Sc.

ONE of the chief advances in plant physiology attained during the present century has been the demonstration that the list of nutrient elements essential for plant growth is not exhausted by the classical nutrient solutions containing only hydrogen, oxygen, nitrogen, sulphur, phosphorus, calcium, potassium, magnesium and iron. To-day it is generally accepted that at least two additional elements are required by higher plants, namely boron and manganese, and there is a considerable body of evidence to suggest that the same is true of metals such as copper and zinc. There is indeed a tendency in some quarters to assume that all elements, of which traces have been detected in plant ash, play essential rôles in plant functions. As a result, modern culture solutions, compounded from highly purified chemicals, tend to become more and more complex.

The earliest record of boron as a constituent of plant ash appears to be that of Wittstein and Apoiger, who in 1857 obtained boric acid from the ash of seeds of an Abyssinian plant. Subsequent investigations show that boron occurs in the ash of higher plants in small but fairly constant proportions, varying usually between 0.1 and 0.5 per cent. Brown algæ, on the other hand, contain a greater quantity of the element, about 1 per cent. of the ash.

In 1910 Agulhon published results of experiments showing increase in dry weight, over that of the control without boron, of wheat, oats and radish grown in sand cultures with 0.5 mg. boron per 2 kg. of sand and concluded that "boron is a useful element for higher plants."

Agulhon, however, gave no proof that normal growth was impossible in the absence of boron, nor did he describe symptoms by which boron deficiency might be diagnosed. The first of these requirements was furnished by Mazé (1915) in the case of maize, but it was left for Warington (1923) to show conclusively that boron is not only a growth stimulant, but that in its absence members of the order *Leguminosæ* developed constant and easily recog-

nisable symptoms of malnutrition. Such symptoms could be prevented in the case of broad bean (*Vicia faba*) by inclusion in the culture solution of 1 part of boric acid in 12,500,000 parts of water. In 1926 Sommer and Lipman published a series of photographs indicating greatly increased growth in the case of sunflower, cotton, barley, buckwheat, castor bean, flax and mustard, when supplied with traces of boron in water cultures. In 1928 Johnston, and Johnston and Dore, indicated the essential nature of this element for the normal growth of potato and tomato, and in the following year McMurtrey (1929) provided similar evidence in the case of tobacco.

A great impetus to the study of the problem was provided in 1931 by the work of Brandenburg, which for the first time clearly demonstrated that boron deficiency is a noteworthy factor in agricultural practice since it is the cause of that widespread and serious disease of sugar beet and mangolds, heart rot. Since that date general attention has been attracted to the subject, and our knowledge has made rapid progress.

SYMPTOMS OF BORON DEFICIENCY

The most reliable diagnostic symptom of boron deficiency in higher plants is death of the apical growing point of the stem. This is generally followed by stimulation in the growth of lateral buds, resulting in the formation of side shoots, which in turn die back at the tip. Leaves of affected plants are commonly slightly thickened, often tend to curl and may become slightly chlorotic. Frequently the petioles are noticeably brittle and in many cases the plants fail to bloom, or to set fruit. A further symptom, recorded in all cases studied in detail, is stunting of the root system, particularly a check to the development of fibrous lateral roots. Histological symptoms include degeneration of all meristematic tissues both terminal and intercalary, discoloration and breakdown of parenchymatous cell walls followed by collapse of the cells, phloem necrosis and, frequently, lack of full normal development, especially in the root.

As will be seen from the table on page 60 (Table I) this general symptom-picture holds good in the case of tobacco, tomato, potato, sugar beet, broad bean and citrus, although the relative importance of the different components varies according to the habit and growth of the plant concerned. It seems to apply also to a number of plants which have been less intensively studied such as lettuce, celery and probably cotton and apple. The table shows two main exceptions to the general scheme, namely the

TABLE I

REVIEW OF THE RECORDED SYMPTOMS OF BORON DEFICIENCY IN ECONOMIC PLANTS

	Tobacco.	Tomato.	Potato.	Sugar Beet.	Broad Bean.	Swede.	Citrus.	Lettuce.	Celery.	Cotton.	Sugar Cane.	Maize.	Apple.
Death of apical bud . . .	x	x	x	x	x	In water culture	x	x	x	—	x	—	x
Stimulation of side buds .	x	x	x	x	—	—	x	—	—	—	—	—	—
Failure to bloom	x	x	x	—	x	—	—	x	—	x	—	—	—
Chlorosis . . .	x	x	x	x	—	—	x	—	—	x	x	x	—
Browning or mottling of leaves	—	—	—	—	—	—	—	x	x	—	—	—	—
Leaf curl . . .	x	x	x	x	—	—	x	—	—	x	—	—	—
Leaf thickening	x	x	x	—	"Leathery"	—	—	—	—	—	—	—	—
Brittleness of petiole . . .	x	x	x	x	—	—	—	—	x	—	—	—	—
Stunted root system . . .	x	x	x	x	x	x	x	—	x	—	—	—	x
Cell enlargement	x	x	—	x	x	x	—	—	—	—	x	—	—
Discoloration of parenchymatous cell walls	x	x	x	x	x	x	—	—	—	—	—	—	x
Phloem necrosis	x	x	x	x	x	—	—	—	—	—	—	—	—
Root xylem under-developed	x	x	x	—	x	—	—	—	—	—	—	—	—
Death of cambium . . .	x	x	x	—	x	—	x	—	—	—	—	—	x
Translocation impeded . .	x	x	x	x	x	—	x	—	—	—	—	—	—

Swedish turnip and the *Gramineæ*. The case of the former does not really provide a serious discrepancy, since the normal features of death of the apical meristem and stunting of the root system, develop in the complete absence of boron from the water cultures. The interesting point here, is that under conditions of mild boron deficiency, such as occur in the field, the diagnostic symptom is not a necrosis of the meristem but a browning of the wall of the parenchymatous storage tissue, giving rise to the disease known as brown heart. The *Gramineæ*, on the other hand, appear to provide a peculiar case. In the first place it seems evident that they require relatively far less boron than do dicotyledonous plants, and secondly, where symptoms of boron deficiency have been artificially induced they are of a peculiar character and take the form of chlorotic stripes on the leaves, as described for maize by van Overbeek (1934) and for sugar cane by Martin (1934). In the case of other *Gramineæ* our knowledge is even less satisfactory. Warrington (1923) was unable to demonstrate conclusively any

favourable influence of boron applications to barley seedlings either in water or soil cultures. Sommer and Lipman (1926), on the other hand, have published photographs showing enormous differences in bulk of foliage in favour of barley seedlings supplied with boron as against those without boron. Their success in demonstrating the essential nature of a trace of this element in the case of barley is probably due to the fact that they removed the grain from the seedling a few days after germination and so deprived it at the earliest possible date of the stored material in the endosperm. The writer has been able to demonstrate that oat seedlings grown in van der Crone's solution without boron became chlorotic, developed numerous stunted secondary roots and died prematurely. Seedlings supplied with 0.005 gm. borax per litre remained green and produced normal roots.

The question of the boron requirement of lower plants has not yet been adequately investigated. Agulhon (1910) was unable to find doses of boron favourable to the growth of yeast or of *Aspergillus niger*. Schmucker (1935) obtained similar results with *Penicillium* sp., *Phycomyces Blakealeanus* and *Spirogyra* sp. It is, however, possible that the latter investigator did not employ a sufficiently low concentration of boric acid to obtain decisive results. Young (1935) records increased growth of *Chlorella* and *Crucigina* in the presence of 20 p.p.m. of boron in nutrient solutions.

FUNCTION OF BORON IN THE PLANT

It may be well in the first place to summarise briefly the evidence which supports the modern view that boron is not merely an element which can be employed to gain an artificial and temporary stimulus to growth, but is essential for the normal nutrition and development of vascular plants.

This evidence may be grouped into four heads:

(1) Boron is accumulated in plant tissue to an extent quite disproportionate to its occurrence in the medium on which the plants are growing. This applies to brown marine algae as well as to land plants and has been clearly demonstrated by Goldschmidt and Peters (1932) who quote an instance in which a beech tree growing on soil containing only 0.001 per cent. B_2O_3 accumulated boron in its wood up to 0.5 per cent. of the ash. Bertrand and Agulhon (1913) have shown that boron is also found in the tissues of most animals, being most easily detected in the hair, bones, horns, liver and muscles.

(2) Minute quantities of boron are required throughout the life of the plant, as has been demonstrated for sugar beet by Branden-

burg (1932), beans by Warington (1923), maize by van Overbeek (1934), tobacco by Johnston and Fisher (1930) and tomato by van Schreven (1935). This indicates that its function is one which persists throughout life, and is not, as implied by Wimmer and Lüdeoke (1934), restricted to young seedlings. It also demonstrates that the element is consumed, or "fixed," in normal metabolism, and does not act as an ordinary catalyst, an initial supply of which would continue active over a long period (Brenchley and Warington, 1927).

(3) In experiments with pure salts under controlled conditions it is not possible to replace boron by any other element (Brenchley and Warington, 1927).

(4) When the supply of boron is withdrawn from a plant, characteristic disease symptoms result, which can be prevented or, frequently, cured by addition of a minute quantity of boron to the nutrient solution.

It is mainly by a study of these symptoms that the normal function of the element can be inferred. The most suggestive results available are those of Schmucker (1933), who demonstrated that pollen grains of tropical water lilies germinated normally in drops of nectar from those flowers, but failed to germinate, or produced germ-tubes which quickly burst, when placed in drops of sugar solution of similar concentration to the nectar. Schmucker showed that addition of 0.001 per cent. or 0.01 per cent. boric acid to the sugar solution prevented bursting of the pollen tube and permitted its continued growth. In a later paper (1935) he reported confirmatory results with the pollen of other plants, but was unable to demonstrate any correlation between sensitivity to boron and the systematic position of the plant. He ultimately concluded that the influence of boron in preventing bursting of the pollen tube indicated that it exerted some control over the swelling of the protoplast, i.e. over its uptake of water. He also conjectured that compounds of boron and sugar may play some part in the formation of the pectin in the pollen tube wall, though he considered it doubtful whether boron entered into the composition of the wall substance itself.

It remains to be seen whether these suggestions derive any support from the expression of boron deficiency in the complex tissues of vascular plants. In this connection it is necessary to consider as far as possible, not the ultimate necrotic effects visible to the naked eye, but the earliest results of deficiency in the individual cells. For this purpose the case of the turnip merits special consideration since in its case there is, under field conditions, no

necrosis of the meristems but merely a deformation of parenchymatous cells. It is therefore significant that Jamalainen (1935) states the first symptom of the disease to be an enlargement of the parenchymatous cells of the xylem, so that they lie close together without intercellular spaces, hence the water-soaked appearance of the diseased tissues. This is confirmed by the writer's observations and is in agreement with Schmucker's description of a swelling of the plasma under conditions of boron deficiency. Examination of the literature indicates that similar cell enlargement has been noted whenever anatomical investigation has been carried out at a sufficiently early stage in the disease; examples are, the cambium of broad bean, bundle sheath of sugar cane, phloem and parenchyma of tobacco and periblem of the root tip in the pea. The first and the last of these citations are of special interest as suggesting that the effect of lack of boron on meristematic tissues is essentially similar to that on other living cells, and is more disastrous in the former merely because they are more active and, in general, more delicate. Jamalainen reports that swedes suffering from brown heart contain a greater percentage of potash in their ash than do healthy swedes. This is possibly significant in the present connection, since potassium tends to increase the water-holding capacity of the plasma colloids and thus acts in the reverse direction to the assumed function of boron. The connection between boron and calcium hinted at by Warington (1934) may point in the same direction since calcium is also an element which tends to reduce the degree of hydration of the plasma colloids. On the other hand, as Loew (1932) has pointed out, calcium is intimately connected with the normal functioning of the cell nucleus and boron may play a similar rôle. Thus van Schreven (1934) has noted that in ground parenchymatous cells of boron-deficient tobacco the nucleus may become discoloured at a time when the cell walls still look healthy. In root-tips of the pea under similar circumstances, the nuclei lost the ability to divide mitotically (Sommer and Sorokin, 1928).

As regards Schmucker's second suggestion, namely that boron is concerned in the formation of pectic substances in the cell wall, there is at first sight a considerable amount of confirmative evidence. Discoloration of, and ultimate destruction of the cell wall has been recorded whenever boron deficiency has been investigated anatomically, and, in many cases at least, it begins in the swelling and discoloration of the middle lamella, the region most rich in pectin. Such a condition, however, is not confined to plants deficient in boron and it seems more plausible to regard the phenomenon as

an expression of interference in carbohydrate metabolism. Pectins are complex compounds including both hexoses and pentoses, combined with galacturonic acid. There is abundant evidence that in the absence of boron, translocation of such carbohydrates, to the regions where disease symptoms are expressed, is impeded. This is most obvious in the case of plants with large storage organs, such as sugar beet and swede, but is also true of other species. The subject has been carefully studied in the case of the tomato by Johnston and Dore (1929), who found that in the absence of boron, sugars accumulated in the leaves to an extent more than double that in the normal plant, the hexose content of stems was greatly reduced while the galacturonic acid content was not significantly altered. This is a further indication that the influence of boron on cell-wall structure is bound up with the control of carbohydrate movement. The disturbance in translocation is not necessarily due to death of the phloem cells, since it occurs to a marked degree in brown heart of swedes, a disease in which the condition of the phloem cells remains apparently unchanged.

In a study of the effect of boron deficiency on the structure and functioning of the bacterial root tubercles in the broad bean, Brenchley and Thornton (1925) found that, in the nodules of plants grown under such conditions, the vascular system was reduced and the bacteria tended to become parasitic, attacking the protoplasm of the host cell. They suggested that this change from the normal symbiotic relationship of micro-organism and host was connected with the reduced carbohydrate supply to nodules of boron-deficient plants.

The effect of reduction in the length of day in delaying the expression of boron-deficiency symptoms (Warington 1933) may possibly also be related to carbohydrate metabolism.

There is a considerable body of evidence therefore to support the view that boron is concerned in regulation of the water relations of the plasma colloids. There is also abundant evidence to show that it is involved in carbohydrate translocation and possibly in carbohydrate utilisation. Most, if not all, of the observed symptoms of boron deficiency find explanation in the interaction of these two primary functions, but it remains for future work to elucidate the relationships between them.

SOURCES OF BORON AVAILABLE TO PLANTS

Although boron is an essential component of some 56 minerals (Schaller, 1929) the majority of these are rare or of restricted occurrence and the only widespread member of the group is tourmaline

boro-silicate of aluminium and iron. The actual boron content of this mineral varies as a rule between 8 per cent. and 10 per cent. B_2O_3 , but may occasionally be much higher. It is doubtful however, whether tourmaline forms a source of boron available as plant food, since it is an extremely refractive mineral, resistant to weathering, which occurs in an unaltered and insoluble form as a component of the heavy residue obtainable from sedimentary rocks. On the other hand, its occurrence in the field in igneous or metamorphic rocks is an indication of the presence of boron in those rocks, whether introduced by pneumatolysis or derived from pre-existing boron in argillaceous sediments affected by thermal or dynamic metamorphism.

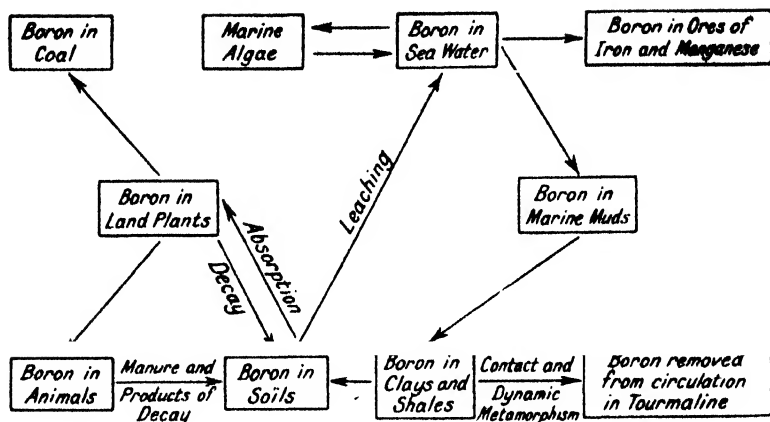
If the boron contained in tourmaline is unavailable for plants, it becomes of importance to determine the distribution of the element as an impurity in other minerals and rocks. The most exhaustive investigations carried out along these lines appear to be those of Goldschmidt and Peters (1932) obtained in a series of spectrographic analyses of European and American minerals, rocks and soils. The boron content of plutonic and volcanic rocks was found to be extremely small, varying between 0.0005 per cent. and 0.001 per cent. B_2O_3 . Calcareous rocks also contained small quantities, ranging from nil in pure chalk up to 0.001 per cent. in limestones and dolomites, but in argillaceous rocks of marine origin, the average content was 0.1 per cent. B_2O_3 . The boron content of German soils was found to vary according to the type of rock from which they were derived, being highest in soils derived from weathering of sedimentary rocks.

According to Bertrand and Agulhon the boron content of seawater is about 56.3 gm. H_3BO_3 per cubic metre, corresponding to 0.1 per cent. B_2O_3 in the marine salts. This is confirmed by the work of Goldschmidt and Peters (1932) who conclude that the boron content of rocks and soils is ultimately derived from the sea, the boron content of the igneous constituents of the earth's crust being only about 0.0001 per cent. to 0.0005 per cent. B_2O_3 . Boron is most abundant in the older marine argillaceous rocks and less so in shales of more recent origin.

Our present knowledge of the boron cycle in nature may therefore be expressed somewhat as in the diagram on page 66.

THE ORIGIN OF A STATE OF BORON DEFICIENCY IN SOILS

From the evidence at present at our disposal it appears that boron deficiency in soils may be of two kinds, primary and induced. From the data quoted in the previous section it is clear that soils



derived from the weathering of magmatic rocks are likely to be poorer in boron than those derived from sedimentary rocks, especially of an argillaceous character. The soils of the South-Western Uplands of Scotland probably afford an example of this type of deficiency, as indicated by the prevalence of brown heart of swedes, even on unlimed fields in Dumfriesshire, Kirkcudbrightshire, Wigtownshire and South Ayrshire. This is a region where the sedimentary rocks are mainly of an arenaceous character, whose poverty in boron is indicated by the almost complete absence of Tourmaline in the aureoles of the three great granitic intrusions of Criffel, Loch Doon and Cairnsmore of Fleet.

Bobko and others (1936) have shown that, as one would expect, the boron content of soils tends to diminish as leaching of the soil progresses. The analyses of Russian soils given in their paper, show the boron content to vary between 0.25 and 0.11 mg. boron per kg. They also state that in Polish soils the boron content varies from 1 mg. to 14 mg. per kg.

There is, however, abundant evidence to show that the actual boron content of a soil is no index of availability of that element for plants. Thus it has long been known that heart rot of sugar beet is most prevalent on alkaline soils and, prior to the work of Brandenburg, the disease was assumed to be directly due to excessive alkalinity. Many recent experiments have shown that the unavailability of boron to plants is closely connected with the amount of lime present. Scharrer and Schropp (1934) have carried out an elaborate series of pot tests with sugar beet in which they showed that addition of 10 gm. of CaCO_3 to 14 kg. of soil increased the tendency to heart rot, and secondly, that addition of boric acid to the limed soil was beneficial in reducing this tendency.

Their work demonstrated that there is in reality no essential relationship between soil alkalinity and development of heart rot, and also that the effect of lime varied according to the type of soil employed, being most severe on a very sandy soil. Probably it depended in part upon the extent to which the soil solutions were buffered, and partly upon their original boron content, which was not determined.

From the work of van der Poel (1932) it is evident that the field occurrence of boron-deficiency symptoms in Sumatran tobacco is also largely controlled by soil reaction. Typical "Topziekte" only occurs on seed beds of pH 7.7 and over. In plants set out in the field the relationship between the disease and soil reaction is less obvious (Kuijper, 1930).

Brown heart of swedes is exhibited freely in certain districts in Scotland on acid soils, even in cases where lime has never been supplied during the memory of man. It is, however, rendered far more severe by heavy applications of lime.

These facts are most readily explained by assuming that the applications of lime render the pre-existing boron in the soil unavailable for plants, in a manner similar to the known effect of lime on other elements, such as iron (Gill and Carreo, 1920) and manganese. The latter probably affords the closest analogy to the case of boron, since it also is required only in minute quantities, and Mann (1930) has shown that liming decreased the solubility of soil manganese, the rate being rapid with small applications. Manganese became relatively insoluble with applications of calcium carbonate of more than 5,000 lb. per acre.

Recent experiments by Bobko and others (1936), however, tend to show that the effect of lime is not a simple chemical reaction with boron. The results showed that although the amount of soluble boron was considerably reduced by the addition of lime, the quantity of boron fixed was in all cases much less than would have been expected assuming the reaction involved to be:

$$\text{CaCO}_3 + 2\text{H}_3\text{BO}_3 \rightarrow \text{H}_2\text{CO}_3 + \text{Ca}(\text{H}_2\text{BO}_3)_2$$

They point out that applications of boric acid to soil greatly stimulate the processes of nitrification and denitrification, from which it may be inferred that boron is utilised in the metabolism of the bacteria concerned. They accordingly assume that a state of boron deficiency in nature is brought about partly by leaching and partly by the absorption of the element by micro-organisms. On this view the effect of liming would be a combination of direct fixation and of indirect fixation due to increased activity of the soil microflora.

CONTROL OF BORON DEFICIENCY IN AGRICULTURAL PRACTICE

Applications of boron are now recommended to control the following diseases :

(1) Heart rot (Herz-fäule) of sugar beet and mangolds, in Germany, Holland, Belgium, Denmark, Sweden, Russia, Hungary, Switzerland, France, Great Britain, Ireland and the United States of America.

(2) Brown heart (Raan, Vatersott, Marmorering, Ruskotauti) of the Swedish turnip, in Canada, New Zealand, Scotland, Wales, Norway, Denmark and Finland.

Most of the work in controlling this disease has been done with Borax at quantities ranging from about 5-20 lb. per acre.

(3) Topziekte of tobacco in Sumatra.

Kuijper (1930) has shown that application of a solution of 3 parts of boric acid per million of water, at the rate of 3 mg. boric acid per plant, was effective in greatly reducing the incidence of topziekte.

Suggestions have also been made for the use of boron, or boron-containing manures, in the cultivation of cotton (Eaton, 1932), strawberries (Hoagland and Snyder, 1933), celery (Purvis and Ruprecht, 1935), apples (McLarty, 1936), and potatoes (O'Brien and Dennis, 1936).

BIBLIOGRAPHY

1. Agulhon, H., 1910, *Comptes Rendus Acad. Sci.*, **150**, 288-91.
2. Atkinson, J. D., 1935, *N.Z. Journ. of Sci. and Technology*, **16**, 316-19.
3. Bertrand, G., and Agulhon, H., 1913, *Comptes Rendus Acad. Sci.*, **155**, 248-51 ; **156**, 732-5.
4. Bobko, E. V., Matveeva, I. V., Doubachova, I. D., and Philippow, A. I., 1936, *Annales Agronomiques*, **6**, 691-701.
5. Brandenburg, E., 1931, *Phytopathologische Zeitschrift*, **3**, 499-517.
6. — 1932, *Angewandte Botanik*, **14**, 104-228.
7. Brenchley, W. E., and Thornton, H. G., 1925, *Proc. Roy. Soc. Lond.*, B., **98**, 373-99.
8. Brenchley, W. E., and Warrington, K., 1927, *Annals of Botany*, **41**, 167-86.
9. Eaton, F. M., 1935, *Soil Science*, **34**, 301-5.
10. — 1935, *U.S. Dept. of Agric. Tech. Bull.* **448** (131 pp.).
11. Gill, P. L., and Carreo, J. D., 1920, *Journ. of Agric. Research*, **20**, 31-61.
12. Goldschmidt, von, and Peters, C., 1932, *Nach. Ges. Wiss. Göttingen, Math.-Phys. Klasse*, 402-7, 528-45.
13. Haas, A. R. C., and Klotz, L. J., 1931, *Hilgardia*, **5**, 175-88.
14. Haas, A. R. C., 1930, *Botanical Gazette*, **89**, 410-13.
15. Hill, H., and Grant, E. P., 1935, *Scientific Agriculture*, **15**, 652-9.
16. Hoagland, D. C. D., and Snyder, W. C., 1933, *Proc. American Soc. for Horticultural Science*, **30**, 288-93.

17. Jamalainen, E. A., 1935, *Publication No. 72 of the Tikkurila Agric. Expt. Sta.* (German abstract, 107-16).
18. Johnston, E. S., and Dore, W. H., 1928, *Plant Science*, N.S., **67**, 324.
19. — 1929, *Plant Physiology*, **5**, 387-92.
20. Johnston, E. S., 1928, *Soil Science*, **26**, 173-5.
21. Johnston, E. S., and Fisher, P. L., 1930, *Plant Physiology*, **5**, 387-92.
22. Kuijper, J., 1930, *Deli Proef. Sta. de Medan, Sumatra, Vlagschrift* No. 50.
23. Loew, O., 1932, *Angewandte Botanik*, **14**, 169-82.
24. McHargue, J. S., and Calfee, R. K., 1933, *Plant Physiology*, **7**, 161-2.
25. — 1933, *Plant Physiology*, **8**, 305-13.
26. McLarty, H. R., 1928, *Scientific Agriculture*, **8**, 636-50.
27. — 1936, *Scientific Agriculture*, **16**, 625-32.
28. McMurtrey, J. E., 1929, *Journal of Agricultural Research*, **38**, 371-80.
29. Mann, H. B., 1930, *Soil Science*, **30**, 117-42.
30. Martin, J. P., 1934, *The Hawaiian Planter's Record*, **38**, 95-107.
31. Mazé, P., 1915, *Comptes Rendus Acad. Sci.*, **160**, 211-14.
32. Noack, K., 1936, *Die Ernährung der Pflanze*, **22**, 353-61.
33. O'Brien, D. G., and Dennis, R. W. G., 1935, *Scottish Journal of Agriculture*, **18**, 326-33.
34. — 1936, *Scottish Journal of Agriculture*, **19**, 1.
35. — 1936, *The Scottish Farmer*, 14/3/36, 364-5.
36. Overbeek, J. van, 1934, *Mededeelingen van het Phytopathologisch Laboratorium "Willie Commelin Scholten"*, Baarn, **13**, 29-33.
37. Poel, I. J. van der, 1932, *Mededeelingen van het Deli Proefstation te Medan, Sumatra*, 2nd series, No. 78.
38. Purvis, E. R., and Ruprecht, R. W., 1935, *The American Fertilizer*, Sept. 21, 1935.
39. Rowe, E. A., 1936, *Annals of Botany*, **50**, 735-46.
40. Schaller, W. T., 1929, *U.S. Geol. Survey Prof. Paper 158*, 137-70.
41. Scharer, K., and Schropp, W., 1934, *Landwirtschaftliche Jahrbücher*, **79**, 977-99.
42. Schmucker, T., 1933, *Planta*, **18**, 642-650.
43. — 1935, *Planta*, **23**, 264-83.
44. Schreven, D. A. van, 1934, *Tijdschrift over Plantenziekten*, **40**, 98-129.
45. — 1935, *Tijdschrift over Plantenziekten*, **41**, 1-26.
46. — 1935, *Instituut voor Phytopathologie, Wageningen, Med.*, 75.
47. Sheffield, F. M. L., 1936, *Annals of Applied Biology*, **23**, 752-58.
48. Sommer, A. C., and Lipman, C. B., 1926, *Plant Physiology*, **1**, 231-49.
49. Sommer, A. C., and Sorokin, H., 1928, *Plant Physiology*, **3**, 232-54.
50. Warrington, K., 1923, *Annals of Botany*, **37**, 629-72.
51. — 1926, *Annals of Botany*, **40**, 27-42.
52. — 1933, *Annals of Botany*, **47**, 430-57.
53. — 1934, *Annals of Botany*, **48**, 743-76.
54. Wimmer, G., and Lüdecke, E., 1934, *Zeitschrift des Vereins der Deutschen Zucker-Industrie*, **84**, 627-66.
55. Wittstein, A., and Apoiger, F., 1857, *Ann. der Chemie und Pharmacie (Liebig)*, **103**, 362-4.
56. Young, R. S., 1935, *Cornell Univ. Agric. Expt. Sta. Mem.* 174.

RECENT ADVANCES IN SCIENCE

MATHEMATICS. By J. H. C. WHITEHEAD, M.A., Balliol College, Oxford.

THE MATHEMATICAL THEORY OF KNOTS.—By a knot we are to understand just what a sailor or a boy scout does, except that the string, or whatever it is that is knotted, is supposed to form an endless loop rather than a length. In mathematical language, a knot is to be regarded as a closed curve rather than an arc with end-points. Returning to our piece of string, it is fairly obvious what is meant by saying that two loops of string are knotted in the same way, or represent the same knot. Without clarifying this concept at the moment, we can at least say what is meant by an unknotted loop, namely, one which can be laid out on a flat surface without crossing itself, round the perimeter of a circle for instance. Just as one refers to a “reef-knot” it is convenient to refer to any form of knot, including that of an unknotted loop, as a knot, though this has the disadvantage that one has to distinguish between a “knotted” and an “unknotted” knot.

The fundamental problem, still unsolved, is to discover a systematic method for deciding whether or no two loops represent the same knot. As yet we cannot even tell whether or no a given loop is knotted. There is nothing sophisticated about this problem. Imagine yourself presented with a complicated tangle of string consisting of one or more loops. Someone might ask you: “Does this consist of one or of more than one loop?” By a purely mechanical process, such as following an individual loop round and painting it a distinctive colour, you could certainly answer this question. But now suppose you are asked whether or no a single loop is knotted. If the loop is long enough, say 50 feet round, and the tangle sufficiently complicated, you might, failing some systematic method, play about with it for a month and still be no nearer the answer. A short cut to academic fame would be to provide such a method!

As the mathematical theory stands at present the expert is in a slightly better position than the layman. There are certain mechanical tests which one can apply, and so recognise the fact

that many knots are actually knotted. But there are knots which, while knotted, are unrecognisable as such by any of the known tests. To apply the latter one usually starts with a representation of a knot as a plane, polygonal circuit, which may cross itself at certain points. It may be assumed that just two edges of the polygon intersect at any one of the crossing points, and we indicate which of these edges passes over the other. We then have what is called a *knot diagram*, which may be thought of as a bird's-eye view of the knot. It is found that common-sense notions lead to the following definition of equivalence. Two diagrams are *equivalent*, that is to say represent the same knot, if one can be transformed into the other by a finite sequence of deformations, which, in so far as they alter the crossings, are of the types indicated in Fig. 1, together with the deformations inverse to these. The equivalence problem, therefore, is to find out whether or no

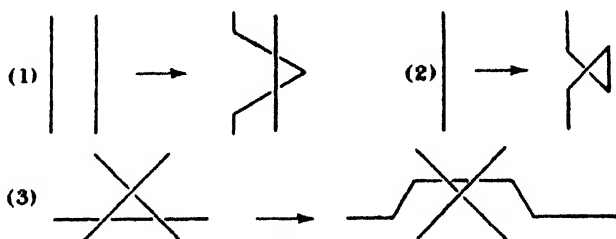


FIG. 1.

two given diagrams can be interchanged by means of these transformations.

A knot invariant is something which can be calculated from the diagram and which is unaltered by these transformations. Nearly all the knot invariants known at present are derived from the group of the knot. This is the fundamental group of the residual space, that is to say the region consisting of the points which do not lie on the knot (the fundamental group of a space is the group described in an earlier article on combinatorial analysis situs [Vol. XXXI, p. 78]). The group is of the kind with a finite set of generators a_1, \dots, a_p , between which there are certain relations. Any product of the generators and their inverses $a_1^{-1}, \dots, a_p^{-1}$ represents an element of the group, and the same element is represented by a product which is obtained from the first by inserting, or omitting, the left-hand side of any relation, or its inverse (when the relations are written in the form $R = 1$, R being a product of the generators and their inverses), or a two-termed product of the form $a_i a_i^{-1}$ or its

inverse. It is to be understood that, if $i \neq j$, $a_i a_j$ need not be the same as $a_j a_i$, and that the inverse of a product $x_1 \dots x_n$ is $x_n^{-1} \dots x_1^{-1}$, where the x 's stand for any of the symbols $a_1, \dots, a_p, a_1^{-1}, \dots, a_p^{-1}$. Of course the same group is represented by infinitely many systems of generators and relations. For example, one can add an extra generator b and a corresponding relation $b = 1$. Also one can replace a pair of relations $R = 1, S = 1$ by the equivalent pair $R = 1, RS = 1$.

A system of generators and relations for the group of a given knot can be found as follows. First let the polygon representing the knot be oriented. Let us describe as a "complete visible segment" one which starts by emerging from underneath some other segment at a crossing, and terminates when it next passes under some other segment, possibly passing over certain segments meanwhile. For example, the segment AB in Fig. 2 is a complete visible segment. To each complete visible segment corresponds a generator of the group. To the crossing marked B in Fig. 2 corre-

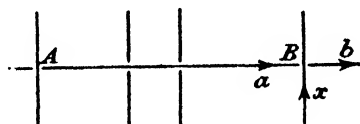


FIG. 2.

sponds the relation $b = xax^{-1}$, or $bxax^{-1}x^{-1} = 1$, and a similar relation corresponds to each crossing (if the orientation of the segment marked x were reversed the relation would be $b = x^{-1}ax$). These are the generators and relations of the group, provided that there is at least one crossing. If there are no crossings, in which case the circuit is unknotted, the group consists of all the powers (positive, negative and zero) of a single generator.

It has been proved that the group so defined is an invariant of the knot. That is to say, the systems of generators and relations written down from equivalent knot diagrams represent the same abstract group. Thus a necessary condition for a given diagram to represent an unknotted circuit is that its group is the free group with a single generator. There is a certain theorem which seems plausible, though no one has yet succeeded in proving it, from which it would follow that this condition is also sufficient. Unfortunately the difficulties in the theory of discrete groups (i.e. groups defined by generators and relations) seem to be at least as formidable as those in the theory of knots. In particular there is no systematic method for finding out whether or no a given

group is of the type just mentioned. Nevertheless, using special methods, one can often prove that a given group is not of this type, and so that some particular knot is actually knotted. Also there is a class of invariants which can be calculated from the group. These are the coefficients of torsion of the n -sheeted Riemann 3-spreads ($n = 1, 2, \dots$) having a given knot as a branch curve (coefficients of torsion were briefly described in the earlier article already referred to), a Riemann 3-spread being a generalisation of what is meant by a Riemann surface in algebraic geometry and the theory of functions. If the given knot is unknotted there is no torsion and so these invariants provide a sieve which catches many knots.

A very simple invariant, which can also be defined in terms of the torsion coefficients just mentioned, is the determinant of the knot. Any knot diagram in a plane divides the latter up into a number of regions. Since precisely four edges meet at a crossing it is easy to verify that one can colour the regions black and white in such a way that no two regions with a boundary edge in common have the same colour. In colouring the regions like this we can clearly choose which of the two colours we assign to a given region. We colour the infinite region R_0 , outside the diagram, black and call the finite regions R_1, \dots, R_n . With each crossing we associate an index 0 or ± 1 . The index of any crossing at which a region touches itself is to be zero. For the rest, if the upper segment, when rotated anti-clockwise into the lower segment, sweeps out a black region the index is $+1$, and it is -1 if a white region is swept out. We then define a determinant $|a_{ij}|$ ($i, j = 1 \dots n$) by the rules: $-a_{ii}$ is the sum of the indices of all the crossings incident with R_i , and a_{ij} ($i \neq j$) is the sum of the indices of all the crossings which are on the boundary both of R_i and R_j . The absolute value of the determinant $|a_{ij}|$ is found to be a knot invariant. If there is a single crossing, the diagram then being a figure of 8, it is clear that the knot is unknotted and that $|a_{ij}| = 0$ (if there are no crossings we let $|a_{ij}|$ take the conventional value zero). Thus $|a_{ij}| = 0$ is another necessary condition for a knot to be unknotted.

There is one other kind of invariant which can be calculated from the diagram of a knot, the so-called Minkowski units of the quadratic form

$$\sum_{i,j} a_{ij} x_i x_j.$$

Though these are the same for large classes of knots, they enable one to distinguish between certain knots with the same group.

Thus the position with respect to the fundamental problem of characterising an unknotted circuit is that one has certain standard tests which exhibit the fact that many knots are actually knotted. If these fail one has nothing to rely on but one's ingenuity which may, or may not, enable one to settle the question by *ad hoc* methods when a particular knot presents itself.

One of the first people to apply mathematics to the study of knots was P. G. Tait (*Scientific Papers*, Cambridge, 1898), who published Part I of a considerable treatise on the subject in 1876. The group was first recognised as a knot invariant by M. Dehn (*Math. Annalen*, **69**, 1910, 137-68). The coefficients of torsion of the covering 3-spreads were introduced by J. W. Alexander (with G. B. Briggs, *Annals of Math.*, **28**, 1927, 562-86; also *Transactions American Math. Soc.*, **30**, 1928, 275-306) and, independently, by K. Reidemeister (*Nach. Wiss. Göttingen*, 1928, 69-76). A good book on the subject is Reidemeister's *Knotentheorie* (Berlin, 1932).

ASTRONOMY. By R. W. WRIGLEY, M.A., F.R.S.E., Royal Observatory, Edinburgh.

LIGHT ABSORBING MATTER IN SPACE.—The importance in all stellar investigations of the possible presence of dark absorbing matter in space has been fully realised in late years, and numerous efforts have been made to determine its density, its distribution, and the nature and extent of its light absorption. Almost all these investigations have been concerned with interstellar matter at great distances from the sun, the dark clouds clustering mainly round the galactic plane. Two recent papers, however, deal with obscuring matter comparatively near to the solar system. In *Meddelande* 61 of the Observatory of Upsala, Carl Schalen describes his examination of the distribution of stars in the Scutum region of the Milky Way. The spectral classes of 2600 stars down to the eleventh magnitude were determined from Harvard photographs taken at Arequipa with the 10-inch Metcalf telescope in conjunction with an objective prism of 3° refracting angle, the region investigated covering about 135 square degrees, and containing part of the rich Scutum cloud, part of the dense region between Scutum and Sagittarius, and, in addition, some very sparse areas further west. The photographic magnitudes of the stars were obtained from six plates specially taken at Harvard and measured with the Schilt photometer at Upsala. They were based on a Harvard sequence containing well determined magnitudes on the International scale. Tables are given showing the distribution in space of stars of types B and A, and of giants of types G5-K2 in different regions. It

appears that the Scutum cloud is a real condensation of stars at a distance of 1300 parsecs, and that the hypothesis put forward recently that the Milky Way cloud formations are only apparent and are caused merely by the contrast of surrounding regions of strong absorption, is not true in this specific instance. Further to the south there is another condensation of stars at a distance of 2000 parsecs, but chief interest centres in a dark area to the west where the number of stars, *including dwarfs*, is greatly decreased for all distances. Schalen infers the presence of a dark cloud of absorbing matter in this region, extending outwards from the near neighbourhood of the solar system, and absorbing about one magnitude for each hundred parsecs. Its presence can be traced to a distance of 300 parsecs, and it probably extends still further. Schalen considers that this and other dark clouds are not isolated agglomerations but belong to the general galactic stratum of interstellar matter.

An investigation with a similar object is described by Axel Corlin of Lund in *Zeitschrift für Astrophysik*, 11. Band, 3. Heft. Two independent methods were employed. In the first, Schlesinger's new catalogue of stellar parallaxes was examined for any evidence of Schalen's dark cloud in the vicinity of the sun. The material consists of 1107 stars at distances between 10 and 50 parsecs, whose trigonometric and spectroscopic parallaxes are both given in the catalogue, and for which it is therefore possible to determine the absolute magnitude M of any star in two independent ways. The presence of absorbing matter between us and the star should leave M (spectroscopic) unaffected but should increase M (trigonometric), making the difference $\Delta M = M_T - M_{SP}$ always positive. This simple method of testing for the presence of absorbing matter would be perfectly valid if there were no systematic difference between M_T and M_{SP} , but, as this is by no means certain in spite of Schlesinger's efforts to put his catalogue on a uniform system, Corlin decided to calculate a mean ΔM for the whole sky and to compare with it ΔM obtained for small areas. For this purpose the 48 equal galactic squares into which Charlier divided the sky were employed, a mean ΔM being calculated for each square. In the second method, the proper motions of 3807 stars taken from Boss' *Preliminary General Catalogue* were utilised to calculate the mean reduced parallaxes by Charlier's method (*Lund Med.*, II, 14), from which the mean absolute magnitudes of stars of different spectral classes were derived.

These two independent methods agree in giving a positive value of ΔM , indicating the presence of obscuring clouds, in the direction

of the constellations Argo, Centaurus, and Scorpio, while in the opposite region of the sky negative values of ΔM are predominant. Corlin considers that these effects cannot be due to either systematic errors or differential galactic rotation, and that they clearly indicate an obscuration of the stellar light commencing from the vicinity of the sun and increasing in amount in the direction of the centre of our local cluster. In other words, the solar system is now moving inside a dark nebula, a fact of some importance in connection with the origin of comets and meteors. It is well known that periodic comets tend to become fainter at each successive perihelion passage, probably through the loss of matter when under the solar influence, and those that develop tails are able to do so probably for only a limited number of appearances. The fact that such comets still exist suggests that they are of comparatively recent origin. It therefore seems possible that the solar system was originally without its surrounding fringe of comets and meteors, and that these belong really to the dark nebula, making their appearance only after the sun and its attendant planets had plunged into it.

Some marked differences between stellar trigonometric and spectroscopic parallaxes have also been investigated by J. A. Hynek of the Perkins Observatory, Ohio (*Publ. Astron. Soc. Pacific*, 1936, Oct.). He gives a list of 70 stars which show striking discrepancies in their absolute magnitudes as determined by the two methods, the trigonometric parallaxes being taken from the *Yale Catalogue* (1935), and the spectroscopic ones from the *Mount Wilson Catalogue of 4179 Stars* (*Contribution*, No. 511). Hynek deals in turn with the following possible causes of the discrepancies: (a) a faulty trigonometric parallax, (b) a faulty spectroscopic parallax, (c) a failure of the mass-luminosity law in the given star, (d) the presence of absorbing material in the line of sight, (e) an error in the determination of the star's apparent magnitude. He considers that (a) is responsible for several of the cases in his list but certainly not for them all, some of the trigonometric parallaxes being very accurately determined. It is difficult to assess the importance of (b), as individual probable errors of spectroscopic parallaxes are not available. As regards (c), the mass-luminosity law is found to hold statistically for single as well as for double stars, but there is, of course, a possibility that it may not always apply to certain individual cases. The effect of (d) was investigated by examining the galactic distribution of the 70 stars. It was found that they showed little galactic concentration, and no correlation with known dark and diffuse nebulae. When plotted in Charlier's 48 equal galactic squares, the number of stars in certain squares was found to be in

harmony with the space absorption found by Corlin, but the maximum effect of the latter was insufficient to account for the discrepancies exhibited by the individual stars. It seems, therefore, that space absorption cannot be the major factor. Similarly, the discrepancies are too large to be explained by errors in the assumed apparent magnitudes, even for the fainter stars in the list. Of the 70 stars tabulated by Hynek, 24 are both spectroscopic and trigonometric dwarfs; 21 are spectroscopic giants but trigonometric intermediates, their trigonometric parallaxes placing them between the two branches of the Russell-Hertzsprung diagram where it was once considered that no stars could lie; 12 are trigonometric dwarfs but spectroscopic giants; 5 are trigonometric giants and spectroscopic super giants, Antares being an example; and 3 only are trigonometric giants but spectroscopic dwarfs. These discrepancies present an interesting problem, the first step to whose solution is undoubtedly a more accurate and reliable determination of the trigonometric parallaxes of the stars in question.

Evidence that the importance of such observations is not being overlooked is provided by the recent publication, as Vol. 8 of the *Transactions of the Yale Observatory*, of the trigonometric parallaxes of 851 stars, determined from 17,000 photographs made with the 26-inch photographic refractor at the Yale Station, Johannesburg, which has now been in commission for nearly 12 years. The objective of the instrument is figured for minimum focus at wave length 4300, the focal length is 10.96 metres, and the scale of the photographs is accordingly 1 m.m. = $18''.82$. This parallax work at Johannesburg is an extension to the southern skies of the programme carried through at Allegheny for the northern. The latter extended southwards to declination -13° while the former is planned to cover the area between $+10^\circ$ and -80° , so the two series will have a common zone 23° wide, about one-fifth of the whole sky. The observations are confined to stars of visual magnitude 5.5 and brighter, having spectra not earlier than A0.

Dr. Schlesinger in his introduction comments on the number of large telescopes now located in South Africa, by means of which, aided by the favourable climate, the leeway in our knowledge of the south celestial hemisphere is being so rapidly overtaken. In addition to the Yale telescope, South Africa can now claim a 24-inch photographic refractor at the Cape, a 26.5-inch visual refractor at the Union Observatory, a 27-inch visual refractor at the Lamont-Hussey Branch at Bloemfontein, a 60-inch reflector and a 24-inch camera at the Harvard Branch at Bloemfontein, two 16-inch cameras at the Leyden Observatory Branch at Johannesburg, while,

most important of all, the construction of the 73-inch reflector for the Radcliffe Observatory, transferred from Oxford to Pretoria, is proceeding apace. All these large instruments, with the exception of the one at the Cape, have been brought into commission within the last dozen years.

In *Proc. Nat. Acad. of Sciences*, **22**, No. 6, Frederick H. Seares has a paper on the "Selective Absorption of Starlight by Interstellar Clouds," based on an examination of the colours of groups of stars, mostly between photographic magnitudes 10 and 13.5, situated in 30 of Kapteyn's Selected Areas covering a wide range in galactic latitude. The differential scattering of starlight in its passage through nebulosity of any kind would naturally redden the stars observed through it, but there have been found certain puzzling abnormalities. Frequently stars of normal colour are found within the boundaries of obscured regions, and, while in some cases it can be inferred that the stars are in front of the cloud and therefore uninfluenced by it, this explanation is not always valid, for it would sometimes imply that the cloud must be sharply bounded and so opaque as to hide all the stars actually within it. A more probable explanation is that some of the stars observed are really within the cloud, but that the latter is composed of particles of such a size as to prohibit scattering of light and leave only a general absorption. Out of 42 groups of stars tabulated by Seares, 23 showed a colour excess equal in the mean to 0.5 mag., and therefore above the limit of permissible error. These 23 groups were found to be mostly within the zone of nebular avoidance or the bordering zones of partial obscuration, but eight of them were situated in latitudes where ordinarily only normal colours would be expected. An important discovery related to stars of class Ao. In unobscured regions their mean colour index was not zero as expected but -0.14 mag.; thus suggesting that the polar region is covered by a veil of obscuration, and that the fixing of the zero point of the international photographic scale was unconsciously influenced by an unexpected colour excess in the polar stars.

These results, down to photographic magnitude 13.5, show a close correlation between selective absorption and the number of visible extra galactic nebulae. Certain areas obscured by specially dense clouds seem to be exceptional, and here the fluctuations in the colour excess are large and apparently unrelated to the general appearance of the fields. It is also noteworthy that the value of the colour excess seldom if ever exceeds one magnitude, and Seares considers that this restriction to an upper limit may eventually prove significant for the fuller interpretation of his results.

A NEW STAR GUIDE.—Amateur observers, whether they use a small telescope or the naked eye, who have some acquaintance with German, will find much useful and interesting information concerning accessible celestial objects in *Am Fernrohr* by Dr. F. Becker (Berlin : Ferd. Dümmler, 1937. Price 2 marks, with 25 per cent. reduction abroad). In its 48 pages it includes descriptions of the constellations, star charts down to the fourth magnitude, lists of double and variable stars, clusters, and nebulae, together with short descriptions of the moon and major planets. There are numerous explanatory figures. This reasonably priced little book can be recommended to all who desire a handy guide to the heavens.

PHYSICS. By W. N. BOND, M.A., D.Sc., F.Inst.P., The University, Reading.

THE FITZGERALD-LORENTZ CONTRACTION.—There are many experiments that have some bearing on the theory of relativity ; but the Michelson and Morley experiment is generally considered to be one of the more important. This experiment, which was originally carried out in 1883, may be regarded as an attempt to measure the motion of the Earth relative to the Luminiferous Æther (*Phil. Mag.*, 151, 449, 1887). Now it is known that the time required to swim to a fixed point a mile away, and to return to the starting point, depends on the magnitude and direction of the water current. Therefore, if light were transmitted in a “luminiferous æther,” and obeyed similar laws, it was to be expected that the apparent velocity of light would change when the apparatus was rotated (for a rotation of the apparatus would orientate it differently with regard to the supposed æther stream). And it was proposed to deduce the direction and magnitude of the earth’s velocity through the æther from the results of the experiment.

Though the experiment has been tried many times, by different experimenters, at various times of the year (lest the earth were on occasions at rest relative to the æther), nevertheless, no variation in the apparent velocity of light comparable with that expected has been observed. The earth appears to be always at rest in the æther. It was therefore suggested that the æther in and near the earth is being dragged along by the earth, so that there is no velocity of the apparatus relative to the æther. But an experiment by Sir Oliver Lodge failed to reveal any “dragging” of the æther near some rapidly rotating discs ; and thus it remained difficult to understand why the motion of the earth through the æther had not been detected.

In 1892, G. F. Fitzgerald suggested that there might be a con-

traction of the apparatus, in the direction of its motion through the æther, of just the magnitude required to make the velocity of light appear to be constant. But when the experiment was repeated (in 1903) using different materials for the apparatus, a null result was again obtained. So it was concluded that the suggested contraction must occur to just the same extent with the new material.

Meanwhile, the investigations of Lorentz (1895) on the mechanics of moving electric charges had indicated that a change in length of just the required magnitude was to be expected, if the distances between the atoms of the solid were dependent on forces between electrical charges. In 1905, however, Albert Einstein made a much more far-reaching suggestion. He assumed that it was not possible by *any* experiment to detect uniform motion through the hypothetical æther.

Let us consider the magnitude of the supposed effects. According to the Fitzgerald-Lorentz theory, a moving body contracts in the direction of its motion through the æther in the ratio 1 to $\sqrt{1 - v^2/c^2}$, where v is its relative velocity and c is the velocity of light. We are ignorant of the velocity of the solar system through the æther, but we know that the earth's orbital speed is about 30 km./sec. (the velocity of light being approximately 300,000 km./sec.). Even if at some part of its orbit the earth happened to be nearly at rest relative to the æther, it would be expected to have a relative motion of about 60 km./sec. when it reached the opposite side of its orbit. Then we should have $v/c = 1/5000$, and a suggested contraction of about 2 parts in 10^8 . Thus, according to this theory, turning the apparatus through a right-angle would (at some time of year) cause a change in length of at least one part in a hundred million.

Another aspect of the Fitzgerald-Lorentz contraction has now been discussed (A. B. Wood, G. A. Tomlinson and L. Essen, *Proc. Roy. Soc., A*, **158**, 606-33, Feb. 1937). In the introduction Wood points out that Lorentz remarked as recently as 1921, "There can be no question about the reality of this change of length." Wood then proceeds to discuss the problem of a rod that is in longitudinal vibration; will its frequency depend on its velocity through the æther? The fundamental frequency N , for a rod of length

l , of elasticity E and density ρ , is given by $N = \frac{1}{2l} \sqrt{\frac{E}{\rho}}$. If there

is a real Fitzgerald-Lorentz contraction of the length l , when the rod is orientated so as to be moving "end on" through the æther, we might expect a corresponding change in the frequency, N , to

occur. But if N were found to be unchanged, it would be concluded that changes had occurred in E or ρ (or both), so as just to compensate for the change in l . It seems unlikely that the density, ρ , will change, because the motion would probably affect the density of the rod equally whether broadside or end-on to the æther drift. Attributing all the supposed compensating effect to a change in E , we should have to assume that the elasticity decreased in the ratio 1 to $1 - \frac{v^2}{c^2}$ and just neutralised the decrease in length, which was in the ratio 1 to $\sqrt{1 - v^2/c^2}$.

Now, of recent years, very accurate methods have been devised for comparing standards of frequency; and quartz rod oscillators are available, which appear to be particularly suitable for the vibrating rod experiment. The quartz rods need not be more than a few centimetres long, in contrast to the 4 or 5 metre arms of the interferometer used in a Michelson and Morley experiment; and hence an experiment on oscillating rods would be free from some of the difficulties (of temperature control, etc.) experienced with the interferometer.

The rest of the paper gives an account of experiments on oscillating quartz rods, carried out by Tomlinson and Essen at the National Physical Laboratory. Before describing these experiments, it may be mentioned that a null result would be of considerable interest. A believer in relativity might predict that the result certainly would be a null one; and he might be but little interested in the suggested details of changes in length compensating change in elasticity. Nevertheless, physics is an experimental science; a null result would give one more foundation for the theory of relativity and a result that was not null would set relativity an awkward problem.

A considerable amount of preliminary investigation was carried out in order to design oscillators that would be free from random fluctuations of frequency. Two horizontal bars of quartz crystal were finally chosen as oscillators. The bars were 54.3 mm. long parallel to the electric axis, and of square section, the sides of the square being 7.5 mm. in the directions of the optic and third axes. Each oscillator was surrounded by central and end electrodes clamped to silica tubes, and was carefully supported by a system of contacts and springs. Each crystal vibrated longitudinally in its first overtone mode, at a frequency of about 100 kilocycles per second; and the rods were carefully ground so that the difference between the frequencies of the two oscillators was about 3 cycles per second. One crystal was in a stationary mounting, and the

other was mounted on a table that could be rotated about a vertical axis.

Each crystal was kept in oscillation by having its electrodes connected to a valve circuit, and these circuits were coupled to valve amplifiers. The outputs of these two amplifiers were connected to the grids of two valves in a single circuit. The combined output was then amplified, to give a current varying sinusoidally with the frequency of the beats (about 3.5 cycles per second). Instead of obtaining a chronograph record of this sinusoidal current, a reed armature relay was interposed, so that the chronograph recorded a series of abrupt pulses, which could be timed to nearer than a thousandth of a second.

The frequency of the beats (which is obtainable from the chronograph record) is equal to the difference between the frequencies of the two crystals. When the one crystal is rotated to a new orientation, the difference between its frequency and that of the stationary crystal can again be obtained. And, hence, any change in frequency due to change in the orientation of the crystal can be measured.

Great care was taken with the crystal mounting and thermal insulation. The electrical circuits were arranged so as not to affect the frequency of oscillation of the crystals and so that they were not affected by any other circuits; all the coils used were toroids, screened by copper cases. And the effects of change in temperature, pressure, applied potentials and so forth were investigated and found to be sufficiently small. In particular, it was found necessary to adjust the rotating mount so that its axis of rotation was vertical. Otherwise there was a slight change in frequency on rotation. This spurious change (possibly due to bending of the crystal) could not be confused with change due to æther drift; for the former passes through one cycle during a rotation of 360° , whereas the latter would pass through two cycles.

The experiment was tried at different times of day and year; and it was found that the frequency did not change with orientation by more than ± 4 parts in 10^{11} . This result fully confirms the predictions of the theory of relativity.

There is hardly any (if any) change in frequency with orientation. It is possible that there really is a Fitzgerald-Lorentz contraction due to the earth's orbital motion through the æther; but if so, more than 99 per cent. of its effect must have been compensated by a corresponding change in the elasticity of the quartz.

These experiments are probably the most accurate that have ever been performed in Physics.

THE MAGNETIC MOMENT OF NEUTRONS.—It may be recalled that in 1932 Dr. Chadwick announced the discovery of neutrons ; entities that have a mass that differs but little from the mass of a proton, but having apparently no nett electrical charge. Ever since their discovery, the question has naturally arisen, have neutrons appreciable magnetic moment ? Several recent papers have some bearing on this topic.

L. J. Laslett (*Phys. Rev.*, **51**, 22, Jan. 1937) explains that certain experimenters have found that iron and nickel produce greater scattering of neutrons (measured in the backward direction) than do neighbouring elements in the periodic table. In order to test whether this greater scattering was due to the ferro-magnetic properties of the scatterer, Laslett compared the scattering at room temperature with that at temperatures above the Curie point. No significant decrease in scattering was observed. Now, at temperatures above the Curie point the scatterer has lost its ferro-magnetic properties. Hence it is concluded that the excessive scattering of iron and nickel is not chiefly due to their ferro-magnetic properties. This does not necessarily imply, however, that the neutron has no magnetic moment.

J. R. Dunning, P. N. Powers and H. G. Beyer (*Phys. Rev.*, **51**, 51, Jan. 1937) give a short account of experiments made to detect any alignment or polarisation of neutrons, due to their magnetic moment, on passing through strongly magnetised materials. The effects produced were small, and in any single experiment they did not much exceed the probable error of the measurement. Taking all the experiments collectively, however, it appeared that the effect was real.

J. G. Hoffman, M. S. Livingston and H. A. Bethe (*Phys. Rev.*, **51**, 214, Feb. 1937) give an account of an attempt to observe the magnetic moment of the neutron through its selective scattering from magnetised iron. An experimental effect of 1.8 ± 0.54 per cent. was obtained. The effect is small, and is only 3.3 times the mean error ; but it appears to be significant. Moreover, the effect agrees with that obtained from an evaluation of Bloch's theory, namely 2.3 per cent.

There is also a theoretical paper (M. E. Rose and H. A. Bethe, *Phys. Rev.*, **51**, 205, Feb. 1937) on "Nuclear Spins and Magnetic Moments in the Hartree Model."

Before leaving this subject, reference may be made to a letter from G. N. Lewis and P. W. Schutz (*Phys. Rev.*, **51**, 369, March 1937). They appear to have detected a refraction of neutrons by paraffin ; and they also state that preliminary experiments strongly

indicate that a beam of neutrons could be focused by means of a paraffin lens.

A NEW DETERMINATION OF h/e .—After a period of disagreement or of suspended judgment, there now appears to be a fair consensus of opinion that the experimental value of the electronic charge is about 4.803×10^{-10} e.s.u.; and that the experimental value of the specific electronic charge is about $e/m = 1.757 \times 10^7$ e.m.u./gm. These values, taken together with Rydberg's equation, are in reasonable agreement with the opinion expressed by Sir Arthur Eddington (*Relativity Theory of Protons and Electrons*, p. 305) that, in general, the uncorrected observational determinations of the natural constants should be consistent with $hc/2\pi e^2 = 137$ and $m_p/m_e = 1834.1$.

However, certain outstanding experimental disagreements still remain. In the previous article (Vol. XXXI, p. 685) reference was made to H. R. Robinson's deduction from his magnetic spectrometer measurements that $h/e = 1.378 \times 10^{-17}$; which agreed well with the value he deduced from Rydberg's equation, namely 1.3799×10^{-17} . On the other hand, he deduced from the work of Kirkpatrick and Ross, and of Schaitberger, on the limit of the continuous X-ray spectrum, the values 1.3754 and 1.3757×10^{-17} .

An account has now appeared (J. DuMond and V. Bollman, *Phys. Rev.*, **51**, 400-29, March 1937) of two precision determinations of the short wave-length limit of the continuous X-ray spectrum (using voltages of about 10,000 and 20,000). From these careful measurements, it is deduced that $h/e = (1.3762 \pm 0.0003) \times 10^{-17}$. This result is in good accord with the X-ray determinations mentioned above; and DuMond and Bollman draw special attention to the fact that these three concordant results disagree with the value deduced from Rydberg's equation. They discuss the matter very fully, but do not find any satisfactory way of accounting for the discrepancy. It does not seem possible to proceed further in the matter till fresh accurate determinations of h/e are made by other methods. It is not unlikely, however, that the disagreement is due to a defect in theory.

THE VALUE OF GRAVITY AT WASHINGTON.—When the accurate value of the gravitational acceleration, g , at any place is discussed, two points of interest arise. Firstly, the question may be asked, why is it desirable to know the value of g accurately? Probably the chief reason for requiring an accurate knowledge of the absolute value of g is that forces are generally measured in terms of the weight of bodies; and the weight of any body is, in its turn, measured as the product of its mass and the gravitational accelera-

tion. The other point of interest is that for the last thirty years it has been the custom to assume the value of g at Potsdam that was obtained by Kühnen and Furtwängler under Helmholtz's supervision (1898 to 1906) and to deduce the value at any other place by a comparison with the value at Potsdam.

An instance of the advisability of knowing the value of g has recently occurred. In preparing for the general use of absolute electrical units, in place of the "International" units that are in use at the present time, a fresh absolute determination of the ampere has been made at the National Physical Laboratory (P. Vigoureux, *Phil. Trans. Roy. Soc., A*, **236**, 133-54, Dec. 1936). The current-balance method was used. By this method, the square of the value of the current in electro-magnetic units is determined as the product of a force and a factor that depends on the geometrical form of the coils but not on their absolute size. Hence the current determination depends primarily on finding the value of \sqrt{mg} , where m is the mass whose weight will keep the coils in equilibrium; and an accurate knowledge of g is essential.

A determination of the value of g at Washington has now been made by P. R. Heyl and G. S. Cook (*Journ. of Research, Nat. Bureau of Stand.*, **17**, 805-40, Dec. 1936); and they compare their results with the value deduced from the Potsdam determination. The result of the new direct determination is given as $(980.08 \pm 0.003$ average departure) cm.sec.⁻². The value deduced by comparison with Potsdam may be taken to be 980.08 ± 0.003 , in good agreement with the new value. But the relative determination had previously been supposed to give a value of 980.100. A correction had formerly been applied which was equivalent to extrapolating from the observed values and deducing the value that would have been given by a pendulum of zero mass. Heyl and Cook do not find that there is any need for such a correction in their own experiments; and it is therefore likely that such a correction should not have been applied in the case of the Potsdam experiments.

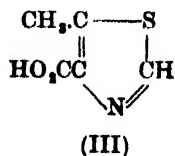
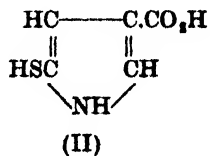
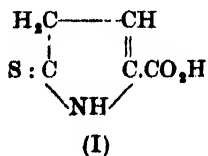
A brief reference may be made to some of the details of the Washington experiments. Four reversible pendulums of fused silica were used, carrying planes of fused silica or of stellite. Various materials were used for the supporting knife edges—fused silica, agate, stellite and Halcomb chrome steel. The pendulums were swung in air at a pressure of about 0.05 mm. of mercury, and were situated in a thermostat room in the basement. A Shortt clock fitted with a photo-electric cell gave pulses of current which were amplified and used to supply a neon lamp; the pendulum was illuminated by this lamp, so that the pendulum and clock could

be compared by the method of coincidences. Finally it may be mentioned that the comparator consisted essentially of a tube of silica, a similar tube being used for the linear scale.

GENERAL AND ORGANIC CHEMISTRY. By O. L. BRADY, D.Sc., F.I.C., University College, London.

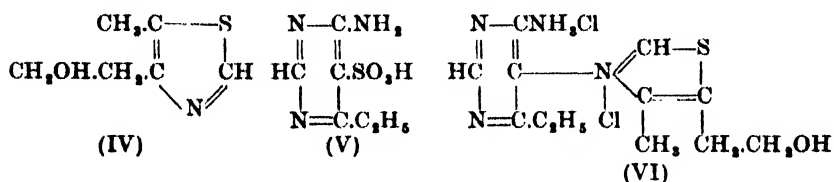
ANEURIN OR VITAMIN B₁.—At the time of writing the last account of the organic chemistry of the vitamins (SCIENCE PROGRESS, 1936, 475), the growth-promoting constituent of vitamin B₂ or lactoflavin had been synthesised; although work on the antineuritic constituent of vitamin B₁ isolable from rice polishings or brewer's yeast, now known as aneurin, had then made considerable progress, it was not described as it was thought that it would, in a short time, be crowned by a successful synthesis; this has now come to pass.

For some time a good deal of discussion occurred as to whether various crystalline products of anti-neuritic activity isolated by various workers from several sources were identical. Numerous empirical formulæ were suggested for these products C₈H₉O₄N₂Cl (Otake, *J. Agric. Chem. Soc. Japan*, 1931, 7, 775), C₁₁H₁₀ON₂S (Windaus and co-workers, *Z. physiol. Chem.*, 1932, 204, 123), C₁₁H₁₁O₄N₂SCl₂ (van Veen, *Z. physiol. Chem.*, 1932, 208, 125), C₁₁H₁₀O₄N₂SCl₂ (Jansen and co-workers, *Rec. trav. chim.*, 1933, 52, 336). By 1935, however, it was generally admitted that the various products were more or less pure specimens of a single compound of empirical formula C₁₁H₁₀ON₂Cl₂S. The first landmark in the determination of the constitution of aneurin was the observation of Windaus, Tschesche and Grieve (*Z. physiol. Chem.*, 1934, 228, 27) that oxidation with nitric acid gave two products C₈H₇O₄N₂, which it was thought might be a dioxymethylpyrimidine and C₈H₇O₄NS which gave a methyl ester and lost ammonia and hydrogen sulphide on warming with alkali. The authors suggested that this compound might be (I) but Niesser (*Ber.*, 1934, 67, B, 2080) synthesised a compound of this structure which was not the same as the oxidation product of aneurin so put forward an alternative (II)

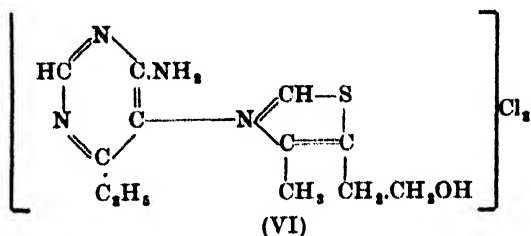
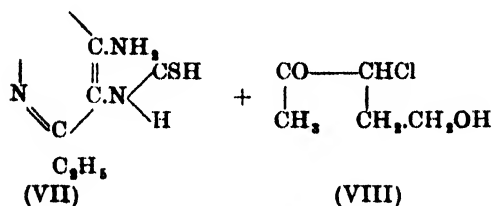


The next important advance was due to Williams and his co-workers (*J. Amer. Chem. Soc.*, 1935, 57, 229, 536, 1849), who found

that aneurin hydrochloride at room temperature with sodium sulphite solution containing sulphur dioxide to bring it to pH 4-5 gave an almost quantitative yield of two compounds C_8H_9ONS and $C_8H_9O_2NS$. The former contained a hydroxyl group and with nitric acid gave Windaus' oxidation product $C_8H_9O_2NS$ which had been shown to be 4-methylthiazole-5-carboxylic acid (III) (Tomlinson, *J. Chem. Soc.*, 1935, 1030; Clarke and Gurin, *J. Amer. Chem. Soc.*, 1935, 57, 1876) and was accordingly given the structure (IV). The second product of sulphite fission was thought to be a 6-amino-pyrimidine sulphononic acid (V) and Williams suggested tentatively the structure (VI) for aneurin itself.



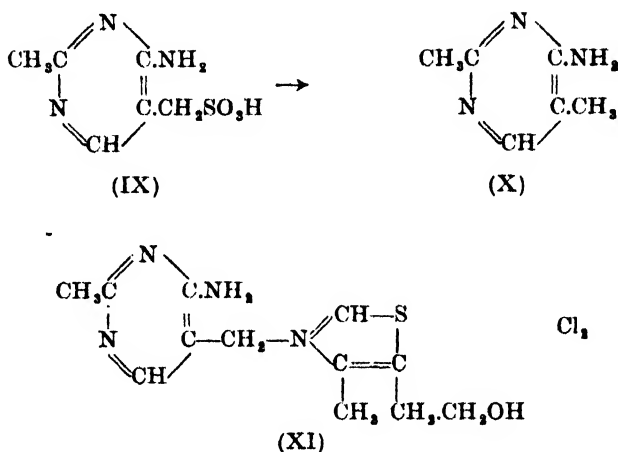
Todd and Bergel (*J. Chem. Soc.*, 1936, 1559) synthesised a compound of this structure by treating the sodium salt of 6-amino-5-thioformamido-4-ethylpyrimidine (VII) with methyl- α -chloro- γ -hydroxypropyl ketone (VIII)



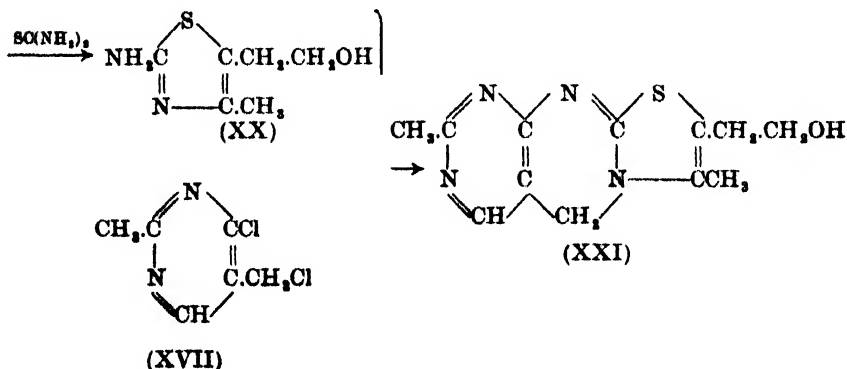
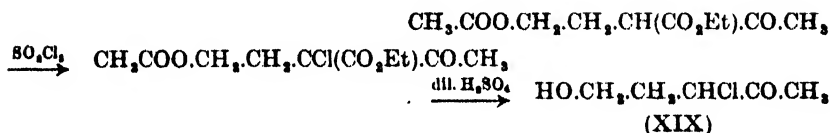
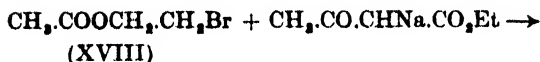
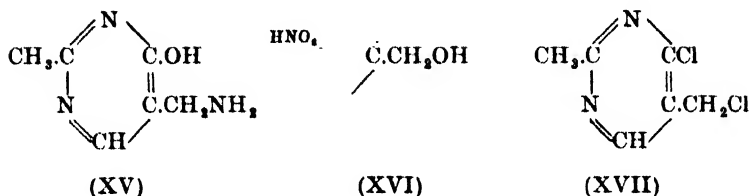
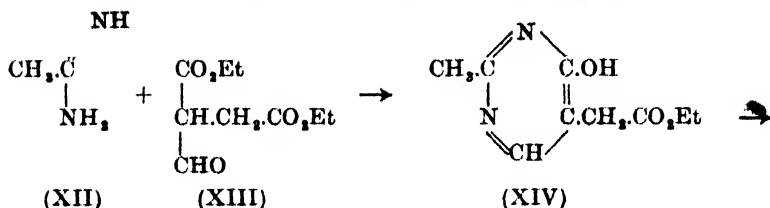
This compound resembled the natural vitamin hydrochloride in appearance and general solubilities but melted 30° lower and had no physiological activity.

Williams (*J. Amer. Chem. Soc.*, 1936, 58, 1063) then showed that the pyrimidine sulphononic acid from the sulphite cleavage of

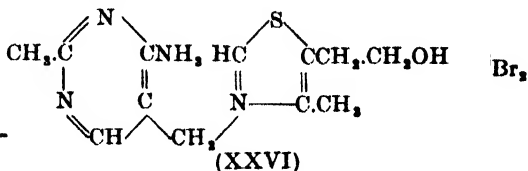
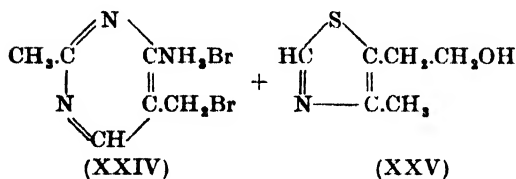
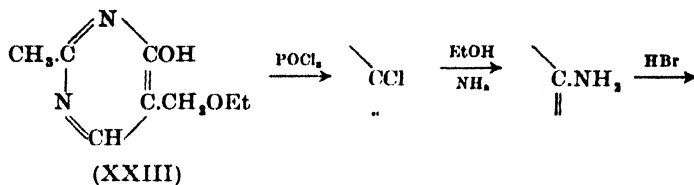
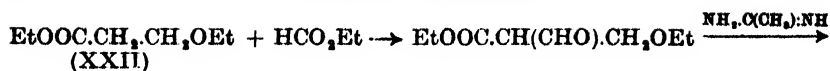
aneurin was (IX) as Cline by the action upon it of sodium in liquid ammonia succeeded in obtaining a small yield of 2:5-dimethyl-6-aminopyrimidine (X). Aneurin hydrochloride was accordingly formulated as (XI).



In the meantime Peters (*Nature*, 1935, **135**, 107) observed that solutions of aneurin on oxidation acquired a blue fluorescence, Kuhn and his co-workers (*Z. physiol. Chem.*, 1935, **234**, 196) isolated a yellow substance from yeast which they called thiochrome which also fluoresced blue in alkaline solution and Barger, Bergel and Todd (*Ber.*, 1935, **68**, B, 2257) obtained thiochrome by oxidation of aneurin with alkaline potassium ferricyanide. Todd and Bergel (*J. Chem. Soc.*, 1936, 1560) suggested the structure (XXI) for thiochrome and Todd, Bergel, Fraenkel-Conrat and Jacob (*J. Chem. Soc.*, 1936, 1601) succeeded in proving this structure by synthesis. By condensing acetamidine (XII) with ethyl formylsuccinate (XIII) they obtained ethyl-4-hydroxy-2-methylpyrimidine-5-acetate (XIV) which by a Curtius degradation gave 4-hydroxy-5-aminomethyl-2-methylpyrimidine (XV). This compound with nitrous acid gave 4-hydroxy-5-hydroxymethyl-2-methylpyrimidine (XVI) which with phosphoryl chloride yielded 4-chloro-5-chloromethyl-2-methylpyrimidine (XVII). β -Bromoethylacetate (XVIII) was condensed with ethyl sodioacetoacetate and the product chlorinated with sulphuryl chloride and hydrolysed to give methyl- α -chloro- γ -hydroxypropyl ketone (XIX) which on condensation with thiocarbamide gave 2-amino-4-methyl-5- β -hydroxyethylthiazole (XX). By heating this compound with the 4-chloro-5-chloromethyl-2-methylpyrimidine (XVII), thiochrome (XXI) identical with that prepared from aneurin was obtained.

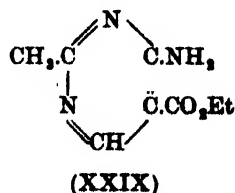
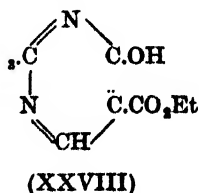
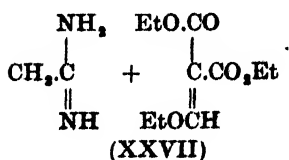


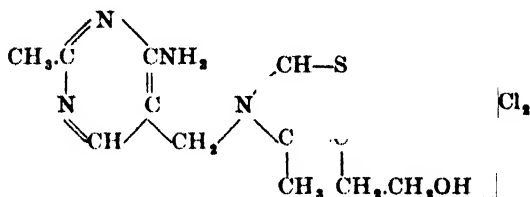
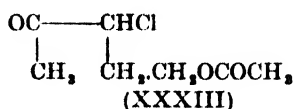
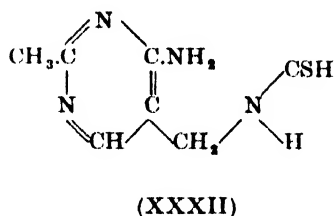
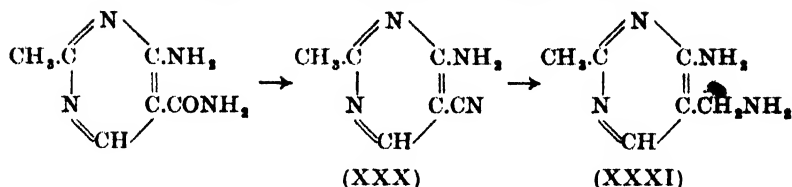
Finally, two syntheses of aneurin have been achieved. Williams and Cline condensed ethyl- β -ethoxypropionate (XXII) with ethyl formate and treated the product with acetamidine and obtained 4-hydroxy-5-ethoxymethyl-2-methylpyrimidine (XXIII) which was converted to the hydrobromide of 4-amino-5-bromomethyl-2-methylpyrimidine (XXIV) which with 4-methyl-5- β -hydroxyethyl-thiazole (XXV) gave aneurin bromide (XXVI).



On conversion to the chloride the product was identical with the natural aneurin chloride in absorption spectrum and anti-neuritic potency but differed in melting point by about 12° . The authors suggest that the natural product is a mixture of stereoisomerides of equal potency.

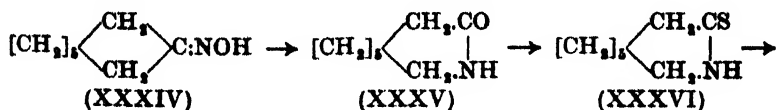
Todd and Bergel (*J. Chem. Soc.*, 1937, 364) condensed ethyl ethoxymethylenemalonate (XXVII) with acetamidine in the presence of sodium ethoxide to give ethyl 4-hydroxy-2-methylpyrimidine-5-carboxylate (XXVIII) which after chlorination with phosphoryl chloride and heating with alcoholic ammonia under pressure gave ethyl 4-amino-2-methylpyrimidine-5-carboxylate (XXIX) which with concentrated aqueous ammonia gave the amide which was dehydrated to the nitrile (XXX) and reduced to the amine (XXXI). With aqueous potassium dithioformate the amine gave 4-amino-5-thioformamidomethyl-2-methylpyrimidine (XXXII) which on heating with methyl- α -chloro- γ -acetoxypropyl ketone (XXXIII) gave aneurin chloride.

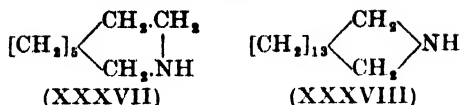




Their product had the same melting point and properties as the aneurin chloride synthesised by Williams and Cline. The authors consider that the difference in melting points between the synthetic and natural products is more likely due to dimorphism than stereoisomerism, especially as oxidation of the synthetic compound gives a thiochrome identical in all respects with that obtained from natural aneurin.

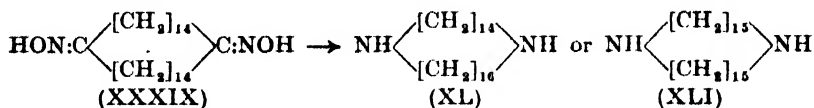
LARGE RINGS.—The interest stimulated by the work of Ruzicka on the preparation of strainless rings consisting of many carbon atoms has led to the production of heterocyclic rings of similar nature. Ruzicka, Goldberg, Hürbin and Boekenooen (*Helv. Chim. Acta*, 1933, **16**, 1323) make use of the Beckmann rearrangement to prepare rings containing nitrogen atoms. For example, *cyclo-octanone oxime* (XXXIV) is converted by sulphuric acid containing 20 per cent. by volume of water to the cyclic amide (XXXV) which with phosphorus pentasulphide followed by sodium hydroxide yields the thioamide (XXXVI). The latter on electrolytic reduction gave an 85 per cent. yield of the cyclic imine (XXXVII).



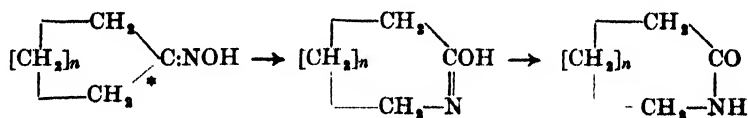


The amide (XXXV) gave very poor yields on direct reduction. *Cyclopentadecamethylene imine* (XXXVIII) was obtained in a similar manner.

Diamines were obtained from diketones, for example *cyclotriacontane-1 : 16-dione dioxime* (XXXIX) gave *cyclodipentadecamethylene imine* (XL) or (XLI).

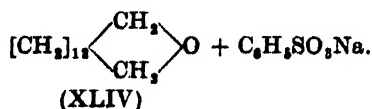
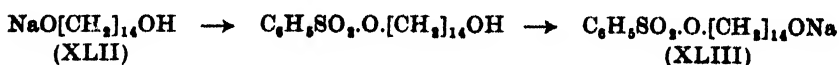


The formation of the cyclic amides from the oximes of large-ring ketones throws an interesting light on the mechanism of the Beckmann rearrangement involved.

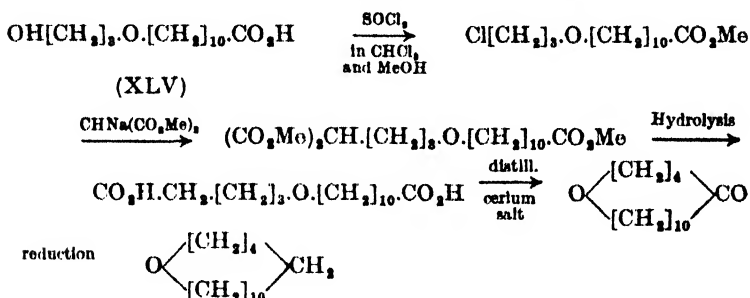


The rupture of the carbon-carbon link * cannot be complete until the CH_2 group is already associated in some way with the nitrogen atom; once the ring was opened one would expect the usual difficulties of closure and the small yields generally associated with the preparation of, for example, nine-membered rings whereas 85–90 per cent. yields were obtained of the cyclic amide from the oximes of both *cyclooctanone* and *cyclopentadecanone*.

Stoll and Scherrer (*Helv. Chim. Acta*, 1936, 19, 735) have recently prepared large rings containing an oxygen atom by treating, for example, mono-sodium tetradecane-1 : 14-diol (XLII) with benzene sulphonyl chloride and boiling the ester with specially prepared finely divided sodium in benzene when the sodium derivative (XLIII) is formed and partly cyclises to (XLIV). The yield of the cyclic compound is only 5 per cent. as side reactions take place.



Another method adopted by these workers starts from hydroxypropoxyundecic acid (XLV) and proceeds as follows :—



INORGANIC COMPOUNDS.—Royen and Hill (*Z. anorg. Chem.*, 1936, **229**, 97) have reinvestigated the hydrides of phosphorus, they have prepared pure liquid hydrogen phosphide and shown it to be P_2H_4 ; previously there had been some doubt of the molecular weight of this compound. To the solid hydrogen phosphide Thénard (*Annalen*, 1845, **55**, 27) gave the formula P_2H and Schenck and Buck (*Ber.*, 1904, **37**, 915) as the result of cryoscopic molecular weight determinations assigned to it the molecular formula P_4H_4 . Schenck and Stock (*Ber.*, 1909, **42**, 2849), determining the hydrogen and phosphorus directly, found that the compound varied considerably in composition and Royen and Hill now suggest that the solid is not a definite compound but consists of amorphous yellow phosphorus with phosphine adsorbed upon it. They have been able to show that considerable amounts of phosphine may be adsorbed by phosphorus.

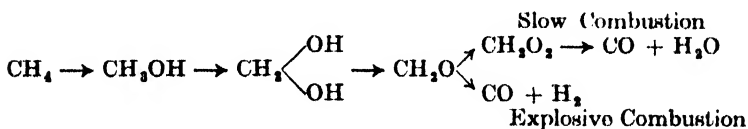
Spencer and Oddie (*Nature*, 1936, **138**, 169) have prepared the hitherto unknown lithium alum by mixing molecular proportions of solutions in the minimum amount of water of the monohydrate of lithium sulphate and the octadecahydrate of aluminium sulphate, concentrating and cooling in ice and salt.

Klemenc, Wechsberg and Wagner (*Z. Elektrochem.*, 1934, **40**, 488; *Z. physikal. Chem.*, 1934, **170**, A, 97) in a study of the decomposition of carbon suboxide have obtained indications of the existence of carbon as a carmine-red gas of the structure dicarbon C_2 . The gas rapidly polymerises to a purplish red solid which gives an X-ray diagram identical with that of graphite. The evidence the authors deduce in favour of the gas being C_2 , namely the appearance in the absorption spectrum of the products of decomposition of carbon suboxide of the head of the Swan band 4737\AA , is not conclusive as some hold the Swan bands are not due to a C_2 molecule (Johnson, *Phil. Trans.*, 1926, **226**, A, 157).

PHYSICAL CHEMISTRY. By H. W. MELVILLE, D.Sc., Ph.D., Colloid Science Laboratory, Cambridge.

THE COMBUSTION OF HYDROCARBONS.—The variety and complexity of the phenomena encountered in the slow and explosive combustion of hydrocarbons appear to be endless—so much so in fact that it would seem to be impossible to bring the general features of the processes within any comparatively simple co-ordinating scheme. Apart from the difficulty of accounting for the numerous products of the reactions, a complete theory must also be concordant with the observed kinetics.

Combustion of Methane.—Systematic analytical studies throughout the course of combustion, made mainly by Bone and his co-workers, have yielded adequate data about the chemistry of the reactions. For example, considering the oxidation of methane, there are produced formaldehyde, methyl alcohol, carbon monoxide, carbon dioxide, water and hydrogen. To explain the occurrence of these products, Bone suggested his so-called hydroxylation theory, as is shown in the scheme below for methane.

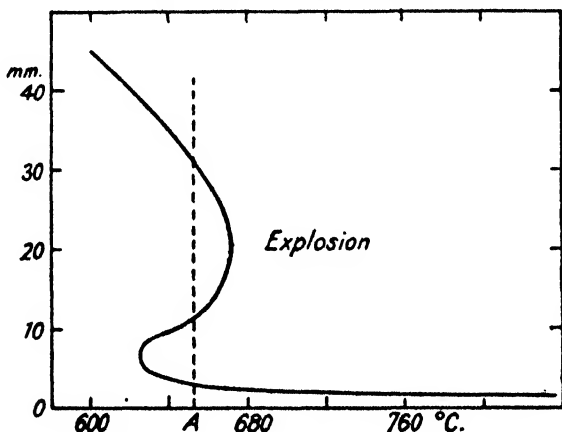


In this oxygen atoms enter the methane molecule producing hydroxylated compounds. These ultimately decompose to formaldehyde which in the slow combustion is further oxidised producing CO and H₂O. In the explosive combustion, however, the formaldehyde is decomposed thermally to CO and H₂, this reaction explaining the appearance of hydrogen in the explosive oxidation.

Early in the development of the chain theory of oxidation reactions, Egerton, Bodenstein and Hinshelwood suggested that the chains were propagated by the formation of peroxides of the hydrocarbons which in turn activated unoxidised reactant molecules so continuing the chain.

All hydrocarbon combustions present certain common features which must be explained in any comprehensive theory. The most remarkable of these is the induction period in which no reaction is detectable manometrically or analytically. The induction period may have a duration of a few seconds or a few hours. It is present in both slow and explosive combustion, but is usually shorter in the latter case. Moreover, it is possible to remove the induction period completely by adding a variety of molecules to the gas mixture. These include aldehydes. The velocity of the ensuing

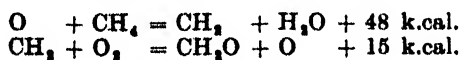
reaction is, however, practically unaffected. Another feature—again a characteristic of a chain reaction—is the large effect of inhibitors such as iodine, the antiknocks, iron pentacarbonyl, tetra-ethyl lead. Yet a second criterion of the occurrence of chains is the strong inhibition of the reaction by packing the vessel. Finally the complicated explosion phenomena require to be explained. The behaviour of methane is typical. The figure shows the explosive region as a function of temperature and pressure for a mixture of given composition. At a temperature A, therefore, there are no less than three ignition limits. The first critical pressure limit



Explosion limits of $\text{CH}_4 + 2\text{O}_2$ mixture (After Neumann and Serbinoff, *Phys. Z. Sov.*, 1, 531, 1932.)

increases in narrower vessels and hence surface processes exercise an important control here, whereas the second limit is unaffected by vessel dimensions. Any theory of the reaction must explain in addition the opposite effect of temperature on the first two limits. Further the onset of explosion is likewise preceded by an induction period of the same duration as that observed in the slow combustion. These are the main features, which are exhibited by methane in particular and to a less degree in the oxidation of other hydrocarbons. Mention of the effect of inhibitors and catalysts will be omitted as it unnecessarily complicates the discussion.

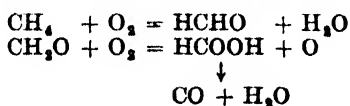
Norrish (*Proc. Roy. Soc.*, A, 150, 36, 1935) has recently sought to explain these results by postulating a very simple scheme for the oxidation of methane, namely



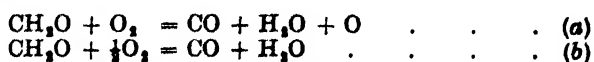
This cycle of reactions only describes the propagation of the reaction

chains. These, however, must be started and also terminated since the reaction velocity is finite. One obvious way in which the chains might be started is by the thermal dissociation of the hydrocarbons into free radicals. But the fact that the temperature (800–1000°) at which methane undergoes pyrolysis to carbon and hydrogen is several hundred degrees higher than that (500–600°) at which oxidation is measured, makes it appear unlikely that reaction is initiated in this way. This does not imply that free radicals cannot initiate combustion at low temperatures. If such radicals were liberated thermally or photochemically there is good reason to suppose that they would start the combustion process. Although it is extremely difficult to prove directly, it would seem that the consensus of opinion is in favour of combustion arising as a result of some heterogeneous reaction. That a chain reaction may be initiated at a gas-solid interface has been proved some time ago. In the hydrogen-oxygen reaction Alyea and Haber (*Z. phys. Chem.*, B, **10**, 193, 1930) showed that a surface is necessary for oxidation by demonstrating the explosion of crossed streams of hydrogen and oxygen in a nitrogen atmosphere on inserting a quartz rod at the same temperature into the gas mixture. Similarly in the phosphorus-oxygen reaction at pressures less than 0.05 mm. the introduction of a hot tungsten filament will initiate a *stable* chain reaction (Melville and Ludlam, *Proc. Roy. Soc.*, A, **135**, 315, 1932). At such low pressures there is no question of heating the gases directly.

It is not unlikely that oxygen atoms for example are ejected into the gas phase by the surface oxidation of the methane thus :



If such be the case the question arises. Why is there an induction period at all? The reaction should start straightaway since the lifetime of an oxygen atom is only of the order of a few milliseconds (*cf.* Hartek and Kopsch, *Z. phys. Chem.*, B, **12**, 327, 1931). The oxygen atoms which escape from the surface initiate a straight chain reaction as is represented by the above equations, one molecule of formaldehyde being produced at each reaction cycle. But formaldehyde also undergoes rapid oxidation at these temperatures probably by two mechanisms



since CO and H₂O are the products of its oxidation. It is important to note that the first reaction gives rise to an oxygen atom which

in turn initiates another separate chain. Effectively, then, *two* oxygen atoms arise for the original one which entered the cycle of reactions. In kinetics the chain is said to branch. Formaldehyde will therefore be produced by the primary heterogeneous reaction and by the branching mechanism and it will be destroyed in reaction (b). On this hypothesis of Norrish, the induction period is the time during which the stationary concentration of formaldehyde is being built up—mainly by the branching process. The reaction velocity will thus attain a maximum value when the concentration of formaldehyde is at a maximum. This explanation of the occurrence of the induction period receives support from the fact that formaldehyde when added in small quantities to the reaction mixture completely removes the induction period. For example, (Norrish and Foord, *Proc. Roy. Soc., A*, **157**, 516, 1936) at 480° with $\text{CH}_4 = \text{O}_2 = 100 \text{ mm.}$, the induction period is about 40 sec., 0.5 mm. CH_2O reduces it to 20 sec. while 2 mm. CH_2O reduces it to less than 1 sec. The maximum rate of reaction is unaffected.

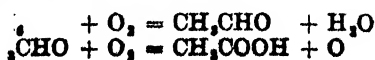
At the end of the induction period the reaction velocity increases exponentially with time according to the equation, $\text{rate} = \text{const. } e^{kt}$. Such a relationship is consistent with the mechanism suggested above. The mathematical development of this will be found in the paper by Norrish and Foord (*loc. cit.*) (*cf.* also Semenov, *Chemical Kinetics and Chain Reactions*, Oxford, p. 57).

In order to account for the kinetics of the slow combustion it is next necessary to enquire into the factors which control the stationary concentration of the short-lived chain carriers CH_3 and O . The reaction velocity will obviously be limited by the slower of the reactions of these carriers. Without going into great detail all the evidence would point to the fact that the reaction $\text{O} + \text{CH}_4 = \text{CH}_3 + \text{H}_2\text{O}$ is somewhat slower than $\text{CH}_3 + \text{O}_2 = \text{CH}_2\text{O} + \text{O}$. Hence the reaction velocity will be wholly controlled by the concentration of oxygen atoms. As has been mentioned, these are formed by the interaction of formaldehyde and oxygen molecules. At pressures of the order of a few hundred millimetres the atoms disappear by diffusion to and combination on the walls as is shown by the fact that the reaction velocity is greater in wider tubes. At very high pressures of the order of several atmospheres, the character of the reaction changes and methyl alcohol is found in quantity in the reaction products (Newitt and Szego, *Proc. Roy. Soc., A*, **147**, 555, 1934). Under these circumstances oxygen atoms cannot diffuse to the walls, but react in the gas phase in a ternary collision $\text{O} + \text{CH}_4 + \text{X} = \text{CH}_3\text{OH} + \text{X}$. At 50 atmospheres where the yield of CH_3OH

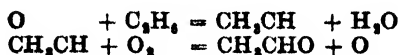
is 50 per cent. there are only twenty bimolecular collisions to every termolecular collision. Owing to the small concentration of oxygen atoms, combination to molecular oxygen in presence of a third molecule is negligible. Substances which increase (NO_2) or decrease (PbMe_4) the oxygen atom concentration thus modify the velocity profoundly when the chains are long. Unfortunately no quantitative measurements have been made of the chain length.

The next question is the mechanism of the onset of explosion. As a consequence of developments in kinetics in recent years, two types of explosion have come to be recognised. They may respectively be termed adiabatic and isothermal. In the first it is supposed that as a result of an exothermic reaction in a gas mixture—not necessarily a chain reaction—the heat accumulates more quickly than it can disappear by conduction, convection and radiation. Reaction velocity increases exponentially with time until a flame appears in the gas. In the second, unlimited reaction velocity may be attained in quite a different manner. In the discussion on the mechanism of the combustion of methane it was shown how it was possible for a reaction chain to branch. Consider a chain of n cycles and suppose the probability of branching is b at any one cycle. The probability of termination at any one cycle will simply be the reciprocal of the chain length, i.e. $1/n$. When these two probabilities are equal, that is $bn = 1$, it is evident that the branched chain will be of indefinite length. This means that only one carrier is sufficient to cause reaction among all the molecules. On account of the minute time scale of collisional processes—at 760 mm. the time between collisions is 10^{-10} sec.—the moment these conditions are satisfied, an explosion will take place. In practice such extremes are rarely encountered and the combustion of hydrocarbons is no exception. It would appear that the explosion itself is the result of an exothermic reaction becoming adiabatic but that the reaction is actually a branching chain process. Branching need not therefore become quite so efficient as in a pure chain explosion. It is simply necessary for the reaction velocity to attain a value so that isothermal conditions cease to prevail in the reaction vessel. The quantitative development of the theory will be found in the papers by Norrish.

Combustion of Other Hydrocarbons.—A similar scheme may be put forward (Norrish, *Proc. Roy. Soc., A*, **150**, 49, 1935) for the oxidation of all saturated hydrocarbons. For example, in the oxidation of ethane a surface reaction of the following type again generate acetaldehyde and oxygen atoms



Oxygen atoms in an analogous manner react thus in the propagation of the chain



while branching as before is due to further oxidation of the aldehyde

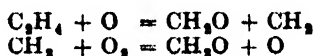


The acetic acid is decomposed to CO and methane which is oxidised as before. The acetaldehyde is largely decomposed to CH_4 and CO which accounts for the large proportion of CO in the reaction products. In the explosive reaction, hydrogen replaces water in the products. This is most likely due to thermal decomposition of formaldehyde formed in the combustion of methane.

Olefines may also be brought within the scheme thus :



and propagation



Termination occurs by the removal of O atoms.

It is evident from this brief survey that the comparatively simple mechanism proposed by Norrish explains the majority of the analytical and kinetic data. Owing, however, to the complexity of the problem, many new data will accumulate on these topics to modify and render more precise the views now current about hydrocarbon combustion. The important role assigned to the methylene radical makes it essential to isolate this radical and study its chemistry in some detail.

DIFFUSION OF GASES THROUGH METALS.—For many years the question of the mechanism of the diffusion of gases through metals has not attracted much attention. Within the past year or so, however, several papers have appeared dealing with this problem from a number of aspects. In 1904 Richardson, Nicol and Parnell (*Phil. Mag.*, 8, 1, 1904) showed that the rate of diffusion could be expressed by a simple formula, namely

$$R = \text{const. } l^{-1} p^{\frac{1}{2}} e^{-E_D/RT} \sqrt{T}$$

where l is the thickness, p the pressure of gas on one side, the other side of the metal being in vacuo. E_D is a constant characteristic of the metal gas system—in this case H_2 —Pt. A considerable number of experiments carried out with other metals and hydrogen supported the validity of this equation. The significance of the $p^{\frac{1}{2}}$ term is that the rate of diffusion is proportional to the concen-

tration gradient of atoms dissolved in the metal, this in turn being proportional to the square root of the pressure of the gas. The exact significance to be attached to E_D was and even yet is not absolutely clear. It is certainly a composite quantity, but in any case is intimately bound up with the energy required to move the atom through the body of the metal. Recently Smithells and Ransley have published a series of papers (*Proc. Roy. Soc., A*, **150**, 172, 1935; *A*, **152**, 706, 1935; *A*, **155**, 195, 1936; *A*, **157**, 292, 1936), critically reviewing all the available experimental evidence on this question. From their own accurate experiments carried out over a very wide range by means of a sensitive technique and from those of others it emerges that the effect of temperature is accurately described by the above equation. Likewise the rate of diffusion is strictly proportional to the square root of the pressure except at low pressures when the rate varies with a higher power of the pressure. Such a departure becomes of less importance the higher the temperature of diffusion. Moreover, the rate of diffusion is sensitive to the treatment to which the surface of the metal has been subjected. As in catalytic reactions, repeated oxidation and reduction of the surface increases the rate of diffusion. All these observations point to the fact that the rate is modified by the amount of gas adsorbed on the surface, this latter concentration in turn controlling the concentration of atoms just inside the metal surface. Employing the simple type of Langmuir adsorption isotherm, i.e. surface concentration = $ap/(1 + bp)$ where a and b are constants, Smithells and Ransley showed that their results could be quantitatively explained by adopting values for a and b which were not widely different from those directly measured in adsorption experiments. The variation of rate of diffusion with pressure consequently becomes

$$D \sim p^{\frac{1}{2}} ap / (1 + bp)$$

which reduces to $D \sim p^{\frac{1}{2}}$ at high pressures when $bp \gg 1$. Such behaviour is exhibited by hydrogen diffusing through Fe, Ni, Cu, Pd, Pt, Mo. Similar behaviour is obtained with aluminium (S. and R., II) though it is necessary to take precautions to prevent the aluminium surface becoming covered with oxide which forms a film impermeable to hydrogen.

According to this view, diffusion is preceded by adsorption. Hence gases which are not appreciably adsorbed on metals should not diffuse through them. It is therefore understandable why nitrogen readily diffuses through iron and molybdenum, but refuses to go through copper and nickel. Naturally the inert gases do not

diffuse through metals though they go through silica glass comparatively easily (Barrer, *J. Chem. Soc.*, 378, 1934). Much controversy has ranged round the question as to whether diffusion of atoms occurs along the cracks and boundaries of the metal crystals or through the metal lattice itself. Smithells and Ransley have decided in favour of the latter alternative, at any rate in so far as hydrogen and iron are concerned, for they have shown that the rate of diffusion is within a few per cent. identical for a fine polycrystalline tube and for a single crystal. It is not unlikely therefore that the diffusion of hydrogen through other metals takes place in a similar manner.

While the departure of the rate of diffusion from the square root law at low pressures is undoubtedly due to adsorption effects, there is a much more serious question at high pressures. The rate of diffusion is governed by the concentration gradient of atoms inside the metal. There ought to be a limit to this when the metal becomes saturated with hydrogen, that is, at sufficiently high pressures, the rate of diffusion should become independent of pressure. Smithells and Ransley (IV) have gone up to 112 atmospheres with hydrogen and nickel finding that the square root law holds accurately.

In any such gas-metal system there are four processes to be considered. (1) Gas molecules strike the surface of the metal and are dissociated to atoms. (2) The reverse of (1). (3) The passage of adsorbed atoms into the metal. (4) The reverse of (3). By considering these processes alone it is not possible to account for the square root law at high pressures where the surface is completely covered with atoms and the concentration inside the metal is at a steady value. To surmount this difficulty, Wang (*Proc. Camb. Phil. Soc.*, 32, 657, 1936) has suggested that when a molecule strikes a vacant place on the surface one atom is adsorbed and the other penetrates inside the metal (process 5). It will be evident at once that this introduces a process which depends on the pressure of the gas outside the metal. The reverse process also occurs (6). The problem then is to deduce an expression to show how D and p are related. Briefly the method is as follows:

At the gas-metal interface processes 1, 2, 5 and 6 are in operation. The *net* rate of adsorption which must equal the rate of diffusion D is therefore given by

$$R = Ap(1 - \theta_1)^2 - B\theta_1^2 + Fp(1 - \theta_1) - G\theta_1 v_1$$

where $A, B \dots G$ are constants, θ_1 is the fraction of the surface covered and v_1 is the concentration of gas atoms just inside the

metal. Similarly the net flow into the metal from the layer of adsorbed atoms is given by

$$R = C\theta_1 - Dv_1(1 - \theta_1) + Fp(1 - \theta_1) - G\theta_1v_1$$

On the vacuum side the same processes are operative but with the signs reversed. Also $p = 0$. Hence

$$R = Dv_2(1 - \theta_2) - C\theta_2 + G\theta_2v_2$$

$$R = B\theta_2^2 + G\theta_2v_2$$

where the subscript 2 refers to the conditions on the vacuum side. In addition there is the equation for diffusion in the metal itself

$$R = E \frac{v_1 - v_2}{l}$$

where E is the diffusion coefficient. First v_1 and v_2 are eliminated, then θ_1 and θ_2 . When p is small, it can be shown that

$$R \sim \frac{1}{2}(A + F)p$$

in reasonable agreement with experiment. On the other hand as $p \rightarrow \infty$, θ_1 and θ_2 both approach unity and $(1 - \theta_1)$ and $(1 - \theta_2)$ are proportional to p^{-1} . Under these conditions the above equations reduce to

$$R^2 \sim \frac{FG(B + C)}{D\left(2 + \frac{Gl}{E}\right)\left[\left(1 + \frac{AG}{DF}\right)\left(2 + \frac{Gl}{E}\right) - 1\right]}p^*$$

as is required by the experiments of Smithells and Ransley. From this equation it will be seen how difficult it is to attach precise significance to the exponential term in the diffusion equation. E_p is certainly not the energy of activation for diffusion through the metal. Though there are a large number of constants in the final equation, a number such as A and F probably have small temperature coefficients whereas B , C , D and G have large coefficients. Lack of exact information on these points precludes a determination of the true temperature coefficient of diffusion from the over-all coefficient. None the less it is interesting to compare the values of the constant in the diffusion equation. The following data (taken from S. and R., 1) show that although E varies from 4,000 to 20,000 cal., the value of the constants almost lie within an order of magnitude.

* Since $R^2 \sim l^{-2}$ this equation reduces to the simple form

$$R^2 = \frac{1}{l^2} \cdot \frac{FE^2}{DG} \left(1 + \frac{AG}{DF}\right)p$$

System.	Mean E. (cal.).	Constant.
H ₂ — Ni	14,000	10 × 10 ⁻³
H ₂ — Pt	19,000	13 × 10 ⁻³
H ₂ — Mo	20,000	9.3 × 10 ⁻³
H ₂ — Pd	4,200	41 × 10 ⁻³
H ₂ — Cu	16,000	0.91 × 10 ⁻³
H ₂ — Fe	9,500	1.6 × 10 ⁻³

Mention has been made of the diffusion of gases other than hydrogen through metals. Nitrogen behaves similarly with iron molybdenum. Oxygen diffuses through silver according to similar laws. The interaction of CO and O₂ with nickel, however, is of rather special interest. Oxygen diffuses through nickel at a measurable rate¹ about 900° C. (S. and R., IV) but the rate is practically independent of pressure above 0.25 mm., though a square root law appears to hold below this limit. From microphotographs of the nickel taken after diffusion has occurred it would appear that NiO is formed on the surface and dissolves in the nickel. Diffusion of oxygen from this solution of NiO in Ni is the rate controlling step when the pressure of oxygen rises above 0.25 mm. It is well known that when nickel is degassed *in vacuo* large quantities of carbon monoxide are given off—a fact which seems to imply the ready diffusion of CO through nickel. On attempting to measure the diffusion of CO through nickel, Smithells and Ransley found it to be far too small to account for the rate of evolution of CO from ordinary nickel. This at once indicated that the carbon monoxide could not diffuse through nickel as CO, but separately as carbon and oxygen. The proof of this supposition was given very neatly by performing the following experiment. A well-outgassed nickel tube carbonised on the inside and oxidised on the outside was heated *in vacuo*. CO collected on the inside and CO₂ on the outside, showing that oxygen could diffuse to the carbon and carbon to the oxide. (It is of interest to note that if it is attempted to diffuse oxygen through nickel the process soon comes to a stop unless a reducing agent such as carbon is ready to remove it as CO.) The question now arises as to whether the diffusion of the oxygen or the carbon is the rate controlling step in the desorption of CO from nickel. From the similarity in absolute rates and temperature coefficients of diffusion of carbon and of CO desorption it would appear that carbon migration is the controlling process.

¹ To remove the oxygen as it accumulates on the high vacuum side the tube was carbonised by heating in a current of acetylene. The oxygen was thus recovered as CO.

GEOLOGY. By G. W. TYRRELL, A.R.C.Sc., D.Sc., The University, Glasgow. **TECTONIC, REGIONAL AND STRATIGRAPHICAL GEOLOGY.**—In a paper on "Geologic Deductions from Earthquakes of Deep Focus" J. S. de Lury (*Journ. Geol.*, XLIII, 1935, 759-64) says: "Seismologists have established the existence of a high degree of rigidity down to great depths, but the commonly held view that earthquakes are of shallow origin has lent support to the opinion that correspondingly shallow rocks alone can permit the slow accumulation of elastic stresses. This opinion must change with the growing evidence that earthquakes probably originate in all levels down to depths of 700 or more kms. The same evidence is disturbing to the assumptions of isostasy and to those hypotheses which rest on the concept of a shell of weakness."

In their paper on "Deep-Focus Earthquakes and their Geological Significance," A. Leith and J. A. Sharpe (*Journ. Geol.*, XLIV, 1936, 877-917) discuss the environment and the characteristics of deep earthquakes. They believe that the type of process involved is probably normal fracturing in response to external stress differences. The possible known sources of stress seem inadequate to act as primary causes of deep earthquakes, but may be important as "triggers." The seismic evidence points to an increase in strength from the surface downwards, and the concept of a weak substratum is therefore believed to be invalid.

Other papers dealing with the condition and dynamics of the interior of the earth are the following: R. A. Daly, "Testing a Theory of the Earth's Interior" (*Journ. Wash. Acad. Sci.*, 25, 1935, 389-99); P. Eskola, "Wie ist die Anordnung der äusseren Erdsphären nach der Dichte zustande gekommen?" (*Geol. Rundsch.*, XXVII, 1936, 61-73); R. A. Daly, "The Sub-Pacific Crust" (*Proc. Fifth Pacific Sci. Cong., Victoria and Vancouver, 1933*. Reprint dated 1934, pp. 2503-10).

The following geophysical papers contain data bearing on the same subjects as above: D. T. Griggs, "Deformation of Rocks under High Confining Pressures" (*Journ. Geol.*, XLIV, 1936, 541-77); P. W. Bridgeman, "Shearing Phenomena at High Pressure of Possible Importance for Geology" (*ibid.*, 653-9); F. Birch and R. B. Dow, "Compressibility of Rocks and Glasses at High Temperatures and Pressures: Seismological Application" (*Bull. Geol. Soc. Amer.*, 47, 1936, 1235-56); J. M. Ide, "Comparison of Statically and Dynamically Determined Young's Modulus of Rocks" (*Proc. Nat. Acad. Sci., U.S.A.*, 22, 1936, 81-92); J. M. Ide, "The Elastic Properties of Rocks. A Correlation of Theory and Experiment" (*ibid.*, 482-96).

An important book on fundamental tectonic and stratigraphical questions has recently appeared; F. Kossmatt, "Paläogeographie und Tektonik" (Berlin: Borntraeger, 1936, 413 pp.), which is the subject of a long review by C. Schuchert entitled, "The Evolving Face of the Earth" (*Amer. Journ. Sci.*, XXXIII, 1937, 308-11). In a suggestive essay entitled "Erdgeschichte und Bewegungsbild der Erde," S. von Bubnoff (*Zeitsch. f. ges. Naturwiss.*, 5, 1936, 185-204) also deals critically with some of the fundamental conceptions of regional stratigraphy and tectonics.

In his Harvard Tercentenary address on "Sedimentation in Relation to Tectonics," E. B. Bailey (*Bull. Geol. Soc. Amer.*, 47, 1936, 1713-26) discusses the use of the criteria of current and graded bedding for stratigraphic sequences and tectonic conditions. He shows that there is a significant connection between graded bedding and geosynclinal depression, where submarine earthquakes function as intermittent distributors of sand and mud. Dr. Bailey passes on to a suggestive discussion of radiolarian cherts and ophiolitic rocks, and their tectonic implications.

Reviewing the "Late Palaeozoic Crustal Movements of Europe and North America," on the basis of the conclusions arrived at by H. Stille and W. H. Bucher concerning epeirogenic and orogenic crustal movements, R. C. Moore (*Bull. Amer. Assoc. Petroleum Geol.*, 19, 1935, 1253-1305) recognises at least nine formations of Post-Devonian times in North America, which are separated by breaks representing earth movements. Times of orogenic movement in Europe appear to be matched by epeirogenic movements in North America. Similarly, orogeny in America is represented by epeirogeny in Europe.

S. von Bubnoff has distributed two excerpts from his *Geologie von Europa*, namely, "Der westeuropäische Bau" (Bd. II, Teil 2, 1936, 1415-24) and "Das Quartär Nord- und Mittel-europas" (*ibid.*, 1425-82) which are valuable summaries of their respective subjects.

In a paper entitled, "Rythmes du métamorphisme dans les Highlands" J. de Lapparent (*Bull. Soc. Géol. France* (5), V, 1935, 281-317) details observations made during the excursion of the International Pre-Cambrian Association to Scotland in 1934. He puts forward some novel ideas as, for example, that the Eilde Flags may be a metamorphosed representative of Cambrian Fucoid beds.

In their important memoir "Perthshire Tectonics: Schichallion to Glen Lyon," E. B. Bailey and W. J. McCallien (*Trans. Roy. Soc. Edin.*, LIX, Pt. I, 1937, 79-116) state that the Dalradian boundary has been shown to be a slide affected by considerable over-

folding. This overfolding has brought into one and the same district Dalradian with and without a Blair Atholl component. Other slides include the Schichallion Slide, as spectacular as any thrust in the North-West Highlands. Large-scale inversion is common in the district. All the big recumbent folding and refolding is towards the south-east.

Through the use of current bedding H. H. Read (*Geol. Mag.*, LXXIII, 1936, 468-76) has been able to show that the stratigraphical order of the Dalradian in the Keith Division of Banffshire is from Cullen Quartzite upwards to Cowhythe Gneiss. Similarly, graded bedding in the Banff Division shows that the order of succession is from Boyne Limestone upwards to Macduff Slates and Grits. The latter part of the investigation shows that it is possible to detect graded bedding and establish the stratigraphical order even in totally recrystallised sediments.

Notwithstanding the difficulty of interpretation of the contact sections J. G. C. Anderson (*Geol. Mag.*, LXXIII, 1936, 535-45) has found it possible to demonstrate that the Girvan-Ballantrae Serpentine is intrusive into Arenig lavas and sediments. Some of the contacts exhibit a narrow belt of shearing within the serpentine in which schistose rocks have been produced. This phenomenon can be readily interpreted if the serpentine is intrusive, but has no meaning if the contact represents an erosion surface.

In "Further Observations on the Ballantrae Igneous Complex, South Ayrshire," D. Balsillie (*Geol. Mag.*, LXXIV, 1937, 20-33) describes metamorphosed dolerites and gabbros, some interesting replacement granites and crush rocks, and also expounds his view that the Ballantrae Serpentine is of Pre-Arenig age. This view is based on observations of foliation, of highly recrystallised pyroxenitic and amphibolitic granulites occurring very close to unaltered Arenig lavas, and on the occurrence of similar recrystallised rocks as boulders within an Arenig agglomerate.

The geology of Inchkeith, an island in the Firth of Forth consisting of Lower Carboniferous sediments with basaltic lavas, intruded by a sill of teschenite, has been the subject of a detailed investigation by L. M. Davies (*Trans. Roy. Soc. Edin.*, LVIII, Pt. III, 1936, 753-86).

The memoir by J. Weir and D. Leitch on "The Zonal Distribution of the Non-marine Lamellibranchs in the Coal Measures of Scotland" (*Trans. Roy. Soc. Edin.*, LVIII, Pt. III, 1936, 697-751), while mainly palaeontological, has many important applications to problems of stratigraphical correlation, both as to horizons in

different parts of the same coalfield, and to horizons in different coalfields. These problems are discussed in full detail.

Owing to the discovery by C. A. Matley and B. Smith (*Quart. Journ. Geol. Soc.*, XCII, 1936, 188-200) of a basal conglomerate with overlying Arenig beds, the age of the Sarn Granite (Lleyn peninsula), so long a matter of dispute, is now definitely proved to be pre-Ordovician, and, by comparison with certain other granites, probably Pre-Cambrian.

"Contributions à l'étude géologiques des Îles de la Manche et du Trégorrois" is a valuable account of the geology of the Channel Islands (mainly Jersey) and of the neighbouring parts of Brittany, which has been written by A. J. Robinson and A. E. Mourant (*Mem. Soc. Géol. et Min. Bretagne*, III, 1936, 100 pp.) as a record of an excursion to Jersey by the Geological and Mineralogical Society of Brittany. There is also included a study of the raised beaches and platforms by A. Bigot, observations and notes by Y. Milon, and a paper on the volcanic rocks of Trégorrois by A. E. Mourant.

In his paper "The Tectonics of the Purbeck and Ridgeway Faults in Dorset," W. J. Arkell (*Geol. Mag.*, LXXIII, 1936, 56-73; 97-118) shows that the accepted view of these fractures as thrusts from north to south is untenable. The Purbeck Fault is a normal fault downthrowing north, and denotes a relaxation of pressure or even tension. The Ridgeway Fault is a reversed fault upthrown on the south side, and has undoubtedly been produced under pressure. Some important stratigraphical and tectonic conclusions follow from this investigation.

An excellent summary of the "Geology of North-East Ireland" is given by J. K. Charlesworth and several colleagues in a paper provided for a summer excursion of the Geologists' Association, and in a Report of the excursion (*Proc. Geol. Assoc.*, XLVI, 1935, 441-86; 493-502). Much new information is skilfully combined with the old. J. E. Richey at the same time discusses the age of the Slieve Gullion Gabbros (*ibid.*, 487-92) which are now shown to be Caledonian, and not Tertiary as hitherto assumed.

In a paper on "Reinterpretation of the Bray Series at Howth, Irish Free State," A. Lamont (*Geol. Mag.*, LXXIII, 1936, 546-50) invokes probable earthquake action and contemporaneous slumping to explain the alternating (greywacke) type of sedimentation and the associated shaly breccias. The quartzites of the Bray Series are interpreted as marine accumulations of aeolian sand derived from surrounding deserts.

In his paper on "Die Umgrenzung der Svekofenniden," H. G.

Backlund (*Bull. Geol. Inst. Upsala*, XXVII, 1937, 210-69) assembles the data for the subdivision of Fennoscandia into a series of orogenic cycles or fold-mountain units, and deals particularly with the delimitation in time and space of the oldest series, the Svecofennides.

The note by H. G. Backlund, "Zur Tektonik des nord-schwedischen Hochgebirge" (*Geol. Rundsch.*, XXVI, 1935, 429-32), is a preliminary explanation of the geological map of the Västerbotten district published in 1929 by Backlund and Quensel. It concerns a region of Caledonian movements in which tectonic and petrogenetic problems are closely associated.

H. von Eckermann's monumental memoir on "The Loos-Hamra Region," Helsingland, Sweden, fills a gap in the Pre-Cambrian stratigraphy of Sweden (*Geol. För. Förh. Stockholm*, 58, 1936, 129-343). The stratigraphy, tectonics, petrography and metamorphism of all formations from the Lower Archæan leptite series to the late Pre-Cambrian Jotnian sediments and igneous rocks, have been very fully dealt with, and important results have been obtained. One of the most important, namely, that the "Sub-Jotnian Unconformity" of Högbom's is non-existent, is further elucidated in the author's additional paper on "The Jotnian Formation and the Sub-Jotnian Unconformity" (*ibid.*, 59, 1937, 19-58). Von Eckermann assembles stratigraphical, tectonic and petrographic evidence to show that the Jotnian represents a single unitary non-orogenic formation, consisting of sediments deposited in an arid region. The series is correlated with the Keweenawan of North America. The Rapakiwi Granites are believed to be magmatically consanguineous with the Jotnian diabbases.

R. Norin's memoir "Contributions to the Geology of Western Blekinge" (*Geol. För. Förh. Stockholm*, 58, 1936, 481-560) concerns a region in the south of Sweden consisting of Archæan supercrustal rocks of the Leptite formation, which have been intruded and migmatitised by a number of later, but still Archæan, gneiss-granites and ordinary granites. It is probable that at least one of the granites is of paligenetic origin.

The following are two recent publications on the geology of Spanish mountains in the well-known Göttingen series edited by H. Stille: "Beiträge zur Geologie der westlichen Mediterrangebiete," No. 12, H. Karrenberg, "Die postvariscische Entwicklung des Kantabro-Asturischen Gebirges (Nordwestspanien)" (*Abh. Ges. Wiss. Gött. Math.-Nat. Kl. III*, Heft 11, 1934, 104 pp.); No. 13, P. Misch, "Der Bau der mittleren Sudpyrenäen" (*ibid.*, Heft 12, 1934, 168 pp.). These two works are fully reviewed in *Geogr. Journ.*, February 1936, 158-60.

An enormous work by R. von Klebelsberg, "Geologie von Tirol" (Berlin: Borntraeger, 1935, 872 pp.), is also reviewed in the *Geogr. Journ.*, February 1936, 162-3.

The following are some recent papers on Russian tectonics and stratigraphy: K. N. Paffenholz, "The Basin of Lake Gokcha (Sevan). Geological Outline" (*Trans. United Geol. and Prospecting Service, USSR.*, Fasc. 219, 1934, pp. 1-94 [Russian], 95-105 [English summary]); A. Zakrevska, "Description géologique et géomorphologique du Poléssié de Tchernigov (entre les rivières Desna et Dniro)" (*Acad. Sci. d'Ukraine. Trav. Inst. Géol. Kiev*, Livr. III, 1936, pp. 1-178 [Russian], 179-82 [French résumé]); M. M. Tetiayev, "On the Question of Tectonic in North Caucasus" (*Problems of Soviet Geology*, V, No. 10, 1935, 901-21); N. N. Dinguelschedt, "On the Subject of Stratigraphy and Tectonics of the South Urals" (*ibid.*, No. 8, 1935, 745-64). N. I. Svitalsky (*ibid.*, No. 5, 419-40) summarises the main tasks that await Russian geologists in attempting to correlate the Pre-Cambrian of European Russia with that of the rest of Europe.

In view of the Northern Excursion (Kola Peninsula and Murmansk) which is to take place before the International Geological Congress at Moscow in July, the following works are of the utmost value: A. A. Polkanov, "Geological Review of the Kola Peninsula" (*Trans. Arctic Inst. USSR.*, LIII, Geology, 1936, pp. 1-146 [Russian], 146-64 [English summary], 164-71 [Bibliography]); A. A. Polkanov, "Geological Outline of the Eastern Part of Fennoscandia—Kola Peninsula and Carelia; and the Actual Geochronologic Problems on the Radioactive Disintegration" (*Bull. Acad. Sci. USSR.*, 1936, 421-44, 441-4 English summary); S. von Bubnoff, "Die Halbinsel Kola" (*Geol. Rundsch.*, 28, 1937, 1-47).

The geology of Arctic regions is represented by the following memoirs: B. Y. Milordovitch, "On Upper Silurian Tillite-like Deposits of Novaya Zemlya" (*Problems of Soviet Geology*, V, No. 11, 1935, 1030-6); H. Büttler, "Die Mächtigkeit der Kaledonischen Molasse in Ostgrönland" (*Mitt. Naturf. Ges. Schaffhausen*, XII, 1935, 17-33); and H. Frebold, "Geologie von Spitzbergen, der Bäreninsel, des König Karl- und Franz-Joseph-Landes" (Berlin: Borntraeger, 1935, 195 pp.), which may be regarded as the modern equivalent of Nathorst's classic memoir of 1910. It is fully reviewed by K. S. Sandford in *Geol. Mag.*, LXXIII, 1936, 92-3.

Recent interest in the geology of Newfoundland is exemplified by the publication of the following memoirs: C. Schuchert and C. O. Dunbar, "Stratigraphy of Western Newfoundland" (*Geol. Soc. Amer., Memoir 1*, 1934, 1-123); G. R. Heyl, "Geology and

Mineral Deposits of the Bay of Exploits Area" (*Newfoundland : Dept. of Natural Resources, Geol. Sect., Bull. No. 3, 1936, 66 pp.*).

The "Geology of Chaleur Bay," in the geologically famous Gaspé peninsula, is the subject of a memoir by F. J. Alcock (*Canada : Geol. Surv. Mem. 183, 1935, 146 pp.*). The formations range from Upper Cambrian to Pennsylvanian.

The "Notes on the Pre-Cambrian of the Canadian Shield with References to Pre-Cambrian Nomenclature," assembled by the late R. W. Brock, have been published with a prefatory note by T. C. Phemister (*Geol. Mag., LXXIII, 1936, 119-41*). Brock recognised four cycles of sediments, volcanics and intrusions, separated by one small and two great unconformities. He makes a comparison between the Canadian Pre-Cambrian sequence and that established by Sederholm for Fennoscandia.

The memoir by C. K. Leith, R. J. Lund and A. Leith on the "Pre-Cambrian Rocks of the Lake Superior Region" (*U.S. Geol. Surv., Prof. Paper 184, 1935, 34 pp.*) is "a review of newly discovered geologic features with a revised geologic map," bringing the geology of this classic Pre-Cambrian region up to date from the great monograph on the same subject published in 1911. The well-known "iron formations" are assigned to Middle and Upper Huronian ages, and the theories of their origin are reviewed. The three great periods of granitic intrusion—Laurentian, Algoman and Killarnean—are more closely delimited. The significance of the terms "Archæan" and "Algonkian" is now mainly petrological, and not chronological as in the earlier memoir.

The following are some recent large memoirs on various aspects of the stratigraphical and regional geology of the western United States : T. S. Lovering, "Geology and Ore Deposits of the Breckenridge Mining District, Colorado" (*U.S. Geol. Surv., Prof. Paper 176, 1934, 64 pp.*) ; T. B. Nolan, "The Gold Hill Mining District, Utah" (*ibid., Prof. Paper 177, 1935, 172 pp.*) ; A. A. Baker, C. H. Dane and J. B. Reeside, Jr., "Correlation of the Jurassic Formations of Parts of Utah, Arizona, New Mexico and Colorado" (*ibid., Prof. Paper 183, 1936, 66 pp.*) ; N. E. A. Hinds, "Uncompahgran and Beltian Deposits in Western North America" (*Carn. Inst. Washington, Publ. No. 463, 1936, 53-136*) ; K. C. Dunham, "The Geology of the Organ Mountains" (*New Mexico School of Mines. State Bureau of Mines and Mineral Resources, Bull. No. 11, 1935, 272 pp.*). The last-named memoir deals with a region in New Mexico which consists mainly of a great granite batholith covered with Palæozoic rocks. This block was uplifted towards the end of the Cretaceous, and then covered with rhyolites, andesites and

basalts of Tertiary age. A large intrusion of monzonite then invaded the complex, bringing in the ore deposits of the region. This memoir is replete with valuable stratigraphical and petrographical detail.

L. Rutten's paper on "Alte Land- und Meeresverbindungen in West-Indien und Zentralamerika" (*Geol. Rundsch.*, 26, 1935, 65-94) is a valuable summary of recent literature which should be noted in connection with Professor Schuchert's recent book (reviewed in *SCIENCE PROGRESS*, Oct. 1936, p. 374). W. Bowie's "Significance of Gravity Anomalies at Stations in the West Indies" (*Bull. Geol. Soc. Amer.*, 46, 1935, 869-78) should also be read in the same connection.

A long but unsuccessful search for oil in western Algeria has nevertheless had its value for regional geology in the publication of a magnificent memoir by R. van Vleck Anderson entitled "Geology in the Coastal Atlas of Western Algeria" (*Geol. Soc. Amer., Mem.* 4, 1936, 450 pp.). The rocks are mainly Tertiary and have been subjected to strong orogenic movements.

Another fine memoir in the same series is A. C. Veatch's "Evolution of the Congo Basin" (*Geol. Soc. Amer., Mem.* 3, 1935, 183 pp.), which has been reviewed by C. Schuchert in "The Congo Basin in its Relation to the Rest of Africa" (*Amer. Journ. Sci.*, XXXI, 1936, 67-73).

In his great memoir on "East African Plateaus and Rift Valleys" Bailey Willis (*Carn. Inst. Washington*, 1936, 358 pp.) attributes the origin of the plateaus to the swelling of a hypothetical asthenolith, and the bounding rift valleys to the failure of the walls of the molten mass. The theory is explained in more detail in a review by R. T. Chamberlin (*Journ. Geol.*, XLV, 1937, 216-19).

Sir Lewis L. Fermor has published "An Attempt at the Correlation of the Ancient Schistose Formations of Peninsular India" (*Mem. Geol. Survey India*, 70, Pt. 1, 1936, 51 pp.), which is the subject of reviews by J. A. Dunn (*Geol. Mag.*, LXXIV, 1937, 185-7; *Econ. Geol.*, XXXII, 1937, 110-13).

The following are recent works on Himalayan geology: D. N. Wadia, "On the Cretaceous and Eocene Volcanic Rocks of the Great Himalaya Range in North Kashmir" (*Rec. Geol. Surv. India*, 68, 1935, 419); D. N. Wadia, "The Trend-line of the Himalaya—its North-West and South-East Limits" (*Himalayan Journ.*, VIII, 1936, 63-9); L. R. Wager, "The Arun River Drainage Pattern and the Rise of the Himalaya" (*Geogr. Journ.*, LXXXIX, 1937, 239-50). In this study the author argues that the Arun is

antecedent to the Himalaya, having been established in its present course prior to the rise of the mountains across the valleys of the southward-running rivers. If this view is correct an important early stage in the surface form of the Himalayan region is established, and some indication of the mechanism by which the range has grown to its present height is given.

C. Schuchert discusses the "Geologic Interpretation of the Bathymetry of the East Indian Archipelago" (*Amer. Journ. Sci.*, XXXII, 1936, 292-7), on the basis of the results of the Snellius Expedition of 1929-30. "The East Indian Archipelago, with its several abyssal intermediate basins and its island festoons with troughs on either side of the lands, makes a highly variable morphological complex that was wrought out of the East Indian mediterranean chiefly through its inherent periodic dynamic action, assisted by the pressures generated by the approaching continents of Asia and Australasia."

R. T. Chamberlin has written a long review of the geological results of the Snellius Expedition (*Journ. Geol.*, XLIV, 1936, 648-650) in which he states that this work constitutes a major contribution to tectonic geology.

Although T. Tomita's memoir on the "Geology of Dôgo, Oki Islands, in the Japan Sea" (*Journ. Shanghai Sci. Inst.*, Sect. II, 2, 1936, 37-146) deals mainly with Tertiary igneous rocks, it is also concerned with stratigraphy. Dôgo consists of Tertiary sediments (Miocene-Pliocene) resting on a basement of gneisses and granites of post-Palæozoic but pre-Jurassic age.

An important Australian stratigraphical memoir is F. W. Whitehouse's "The Cambrian Faunas of North-Eastern Australia, Parts 1 and 2" (*Mem. Queensland Mus.*, IX, Pt. 1, pp. 59, 112, 1936), which is reviewed in *Amer. Journ. Sci.*, XXXII, 1936, 397-8).

In "The Geology of the Region about Preservation and Chalky Inlets, South-West Fiordland, New Zealand" a detailed account of a difficult and inaccessible region is presented by W. N. Benson, J. A. Bartrum and a number of collaborators. These papers will remain authoritative for New Zealand Ordovician geology for a long period. Part I (*Trans. N.Z. Inst.*, 63, 1933, 393-432) gives the Historical Introduction, Summary of General Geology, and Detailed Account of the Unfossiliferous sediments, Igneous Rocks and Tectonics. Part II (*ibid.*, 64, 1934, 51-85) deals with the Evolution of the Modern Topography. Part III (*ibid.*, 65, 1935, 108-52) treats of the Petrology of the Metamorphic and Igneous Rocks, and Part IV (*ibid.*, 244-94) of the Stratigraphy and Palæontology of the Fossiliferous Ordovician Rocks.

PEDOLOGY. By PROFESSOR N. M. COMBER, D.Sc., A.R.C.S., F.I.C.,
The University, Leeds.

IN recent years soil science has lost a number of its most eminent students and no loss to the science has been greater than that brought by the death last year of Georg Wiegner of Zürich. Wiegner brought an extensive knowledge of the pure sciences to bear upon soil problems and his investigation of soil problems did much to extend our knowledge of physical and colloid chemistry.

SOIL WATER.—The relation of the solid and liquid phases in moist soil is still obscure. The general conception that the water at low-water content, and water near the solid particle is very firmly held and that water further from the solid is “freer” is being examined in more detail by various workers.

Kelley, Jenny and Brown (*Soil Sci.*, **41**, 259, 1936) have studied the dehydration curves of mineral soil colloids and compared them with those of minerals of known crystal structure. Their results strongly suggest that the soil colloids contain water of crystallisation as a part of the lattice structure. This water is, however, lost at lower temperatures than the water of minerals of known composition, and this fact has yet to be fully explained.

A good deal has been done to confirm the view, which began to gain ground a few years ago, that at low water content the capillary movement of water is very small. Shiere and Tuinage, for example (*Soil Sci.*, **41**, 351, 1936), carried out experiments in which two, and in some experiments three, horizontal layers of soil were arranged contiguously and with different water contents. Typical of the results is one in which during eleven months the amount of water in an upper layer changed from 4.6 to 5.7 per cent., while in a contiguous lower layer the amount changed from 13.0 per cent. to 12.2 per cent. This means, as other experiments confirm, that it is possible in a soil of low water content for a plant to wilt because of the inability of water very near the root hairs to move forward sufficiently fast to meet the needs of the plant.

Bouyoucos (*Soil Sci.*, **41**, 443, 1936) has examined the relation of the hygroscopic water (i.e. water lost at 110° C.) to the soil particles. He finds that all the hygroscopic water in a mineral soil can be replaced by alcohol and concludes that this water is in film form and not a part of the crystal structure.

Adopting methods and using findings of W. B. Hardy, Weeting (*Soil Sci.*, **41**, 1, 1936) concludes that oriented immovable water molecules are held on the surface of the particles and that a film of such molecules may be 1μ thick before the water is sufficiently free to move to cause the first appearance of plastic properties.

With increasing water of increasing freedom the plastic properties increase until the liquid becomes dominant and the system fluid.

The inadequacy of present knowledge of water movement has led to a rational return to empiricism by Schofield (*Trans. 3rd Congr. Soil Sci.*, 1) who revives, and devises an ingenious experimental method for its determination, the old idea of capillary potential. Buckingham had years ago used the height of a column of water corresponding to the suction power or pressure deficiency necessary to move water from a soil as a measure of this capillary potential, and water was conceived as moving from places of *low* capillary potential to places of *high* potential. Schofield uses the logarithm of the height of the water column and designates it pF . Thus if the suction required to move water from a soil corresponds to the pressure of a water column of 1000 cm. the soil has a $pF = 3$. It is anticipated that in the development of this useful idea it will be possible to relate soil water phenomena to a point on the pF scale in a way that will apply to all soils and that will be independent of any theory of water movement. Thus it appears from the observations of Schofield and Da Costa (*Trans. 3rd Congr. Soil Sci.*, 1) that plants wilt at a $pF = 4.2$.

THE PHYSICAL CONDITION OF THE SOIL.—Apart from mechanical analysis which concerns the prime particles of a soil, the study of the physical condition of a soil in the field has followed two main lines of work. One follows the early work of Keen in measuring the resistance of soils to cultivating implements and the other arises from the study of the shape and consistency of soil aggregates which has been developed in the study of soil genetics. Recently, increasing attention has been given to the measurement of the resistance of a soil to a body forced into it. In this connection some interesting observations are recorded by Culpin (*J. Agri. Sci.*, 26, 22, 1936). He examined the effect of gyrotilling upon (a) the penetrability of the soil to a bullet fired from a 0.45 Webley revolver and (b) the resistance of the soil at various depths to a steel probe—somewhat elaborate machinery was devised for this measurement. Six months after gyrotilling a clay soil, a bullet penetrated to 34.44 cm. but only to 28.26 cm. in the control plots. Twelve months after gyrotilling there was no significant difference between the depths of bullet penetration in treated and untreated plots, but the resistance to a slow-moving steel probe was definitely less in the gyrotilled plots even after nineteen months. Culpin finds that the depth of bullet penetration becomes the same as that in the control plots when the treated soil has settled down to the point of having the same all-over specific gravity as the

untreated and in that sense to have reached the same state of compactness. When the treated soil has returned to its original state of compactness, however, it has not reached its original state of consolidation: its structure is still different and its resistance to the slow-moving probe is still less. The differences shown by plough drawbar tests also persist after the bullet test fails to discriminate between treated and untreated plots.

THE AVAILABLE PLANT FOOD OF SOILS.—The chemical analysis of soils for the determination of the nutritional elements available to plants has obviously engaged chemists since their earliest study of the soil. The early failure of a "complete" analysis to give any indication of the needs of soil in respect of crop husbandry was followed by arbitrary chemical methods. More recently the response of plants to soil treatment in pots and the composition of seedlings have been invoked as means of acquiring knowledge of the manurial requirements of soils. It is now urged by Mitscherlich (*Soil Sci.*, 43, 253, 1937) following discussions at committees of the International Soil Society that, particularly in view of the time taken by pot experiments, laboratory methods for potassium and phosphorus must be investigated and tested against the results of pot experiments. Mitscherlich is convinced that only the plant can really reveal what the soil needs and that laboratory methods must be accepted or rejected according to the verdict of the plant upon their findings.

It is a rather sad fact that all that can be said under "recent advances" on this matter of soil analysis for mineral plant foods is that it is hoped to establish arbitrary laboratory methods the results of which can be accepted on the decision of an empirical pot experiment. The underlying fact of this situation is, of course, that practically nothing fundamental is known about the relation of the plant to the soil. For generations men have studied plants; during the last generation they have studied soils; but the system plant-soil is almost an unexplored field of study.

NITRIFICATION.—The fact that the nitrogen of organic matter decomposing in the soil normally gets into the form of nitrate led to the acceptance of the view that nitrate is, *par excellence*, the nitrogenous food of plants and that nitrification is a wholly desirable process essential to maximum fertility. The facts that nitrate formation in soils involves heavy losses in the drainage water and that plants can use ammoniacal nitrogen which is not lost in drainage, have been adduced to challenge the orthodox view about nitrification. But the early teaching has a strong hold and the alleged importance of nitrification still appears in the current

literature. Thus, Stephenson (*Soil Sci.*, **41**, 187, 1936) argues that nitrification is necessary not only for nitrogen nutrition but because the nitric acid formed in the soil is needed to attack the mineral matter. He says that with nitrification eliminated there are no adequate means of getting either nitrogen or cations into the plant. But against all this is the fact, so strangely ignored, that partial sterilisation eliminates nitrification but enhances considerably the nitrogen fertility and crop-producing power of the soil.

OXIDATION-REDUCTION POTENTIAL OF SOILS.—Whatever may be said about nitrification in particular it is generally recognised that oxidation in a soil is an accompaniment of fertility and that the breakdown of organic matter is essential to the formation and function of soils. A number of workers have therefore attempted the measurement of the oxidation-reduction potentials of soils and some results have seemed to show that the potential is related to crop-producing power. It is therefore important to note the findings of Heintze (*Soil Research*, **4**, 25, 1935). He points out the invalidity of the results obtained by using a platinum electrode, since a film of oxide forms thereon and causes the potential to be affected by the *pH*. Heintze showed that in many cases the intended oxidation-reduction potential is really an approximate measure of the *pH*. In extreme cases (*e.g.* a water-logged soil with much organic matter) reduction influences may play a big part.

SOIL SURVEYS.—A large number of soil surveys have recently been reported upon from all parts of the world, but they are not easily amenable to summary here. A soil map of France (1 to 2,500,000) was published in 1935 by Agafonow, and Stremme's map of Germany (1 to 1,000,000) appeared last year. The soil map of Europe (1 to 2,500,000) is likely to appear soon.

Progress in the genetic study of the soil continues and the publication of the treatise *Pedology* by Joffe in 1936 was very welcome. In the *United States Department of Agriculture Miscellaneous Publication*, No. 229, Kellog very successfully summarises recent knowledge regarding the formation of the soils of the United States "for the general reader." It will be very useful in all countries as giving a concise account of the present position of the subject of soil genetics and classification.

BOTANY. By PROFESSOR E. J. SALISBURY, D.Sc., F.R.S., University College, London.

ANATOMY.—Twenty-two species of *Equisetum* examined by M. A. Johnson (*Bot. Gaz.*, **98**, 595, 1937) all possessed hydathodes of the epithem type on the adaxial face of the leaves, or in species with

very thin or deciduous leaves the hydathodes are situated upon the leaf sheaths. The number of water stomata in the epidermis of each hydathode ranges from 3 or 4, as in leaves on the smaller branches of *Equisetum sylvaticum*, to as many as 50 on *Equisetum giganteum*. The water stomata are similar to the ventilating stomata, but possess no chloroplasts in the guard cells, and the walls are thinner and of more uniform thickness.

In the same journal V. J. Cheadle gives a general account of the well-known *Dracaena* type of secondary thickening in monocotyledons and records this for the first time for *Veratrum viride*, where however the secondary tissue remains largely parenchymatous.

The root anatomy of the Liliaceous genus *Alettris* is described by Holden and Krause (*Journ. Linn. Soc.*, L, 335, 491, 1937); they find evidence that in the various species there is a series of transitional stages from the scalariform vessel perforation to the simple type. The roots are characterised by a peculiar formation of the surface layer in which all the cells are radially elongated and papillate, and there is an absence of root hairs as though all the cells are equally but only slightly differentiated as a piliferous layer. Occasionally the papillar cells contain fungal hyphae.

MORPHOLOGY.—The April number of *Biological Reviews* contains an interesting and valuable consideration of views regarding the morphological interpretation of the flower by Mrs. Arber. The theory is upheld of the equivalence of the flower to a vegetative shoot, though one in which a permanently juvenile state is maintained in certain respects. The Candollean theory of the carpel which has been called in question in recent years is held to be adequate in relation to known facts. The result of a wide consideration of the range of carpel structure fills Mrs. Arber "with wonder at the insight shown by the earlier morphologists in envisaging the carpel and foliage leaf as members of the same category." It may be added that some hypotheses suggest a desire, however unconscious, to provide a novel explanation rather than one which envisages all the facts and gives as much weight to those long known as to those more recently acquired.

ECOLOGY.—The root systems of plants in three types of meadowland in East Finland have been studied by K. Linkola and A. Turikka (*Ann. Bot. Soc. Zool.-Bot. Fennicae Vanamo*, T. 6, No. 6, 1-207, 1936). These meadow types were respectively dominated by *Antennaria dioica*, *Nardus stricta*, and *Alchemilla pastoralis*. The soils of the two latter were wet, of the first named rather dry, the respective water contents of the surface (0-6 cm.) being only 14 per cent. of the fresh weight under the *Antennaria* and about

50 per cent. in the other two communities. All the soils had a reaction approximating to pH6 at a depth of 30 cm. but that of the Nardetum being appreciably more acid near the surface (pH5). The CO₂ in the soil atmosphere was from 0.23 per cent. to 0.32 per cent., according to depth, in the Antennaria meadow; from 0.19 per cent. to 0.46 per cent. at the surface of the Nardetum, rising to 0.99 per cent. at 35 cm. In the Alchemilla meadow the CO₂ content ranged from 0.59 per cent. to 0.95 per cent. at the surface, increasing to over 3 per cent. below 50 cm. The depths of the root systems showed a wide range from only 3 to 5 cm., as in *Trifolium spadiceum*, to from 90 cm. to 155 cm. for *Knautia arvensis*. The same species present in the three communities showed in general a deeper penetration in the drier soils as shown in the data quoted below :

Species.	Antennaria Meadow. W.C. 14% to 7%.	Nardetum. W.C. 51% to 9%.	Alchemilla Meadow. W.C. 50% to 16%.
<i>Deschampsia flexuosa</i>	45- 90 cm.	11-36 cm.	10-33 cm.
<i>Festuca ovina</i>	60- 90	9-40	13-19
<i>Pimpinella saxifraga</i>	74-100	28-59	35-40
<i>Knautia arvensis</i>	90-155	18-28	7-30
<i>Chrysanthemum leucanthemum</i>	25- 36	7-22	6-31
<i>Hypochaeris maculata</i>	68- 80	16-50	8

Very shallow root systems represent 19 per cent. of the Antennaria meadow species as compared with 26-28 per cent. in the other types. Deep-rooted species comprise 42 per cent. of the former and 10-16 per cent. of the latter.

Alternate drying and wetting is often experienced by seeds in nature and therefore the paper by S. M. Griswold (*Bot. Gaz.*, Dec. 1936) is of general ecological interest. He finds that of nineteen species out of 42 which successfully germinated the effects varied according to the species. In four species germination was increased by alternate moistening and drying, whilst in four other species germination was decreased. Rapid drying of the seeds has apparently little effect, but slow drying was found to be generally deleterious. In the same journal H. A. Borthwick reports studies on the effect of calcium in retarding the germination of the seeds of *Hypericum perforatum*, which appears to be due to an effect upon the permeability and not to any change in the reaction.

GEOGRAPHICAL DISTRIBUTION.—A paper by P. L. Anand (*Jour. Ecology*, XXV, 153, 1937) which treats of the marine algal flora of the English chalk cliffs is a valuable contribution to a little-studied subject. The author recognises four belts. A *Fucus* belt

with an average vertical extent of 1.42 m. ; an Enteromorpha belt with an average vertical extent of 0.55 m. ; a belt dominated by Chrysophyceæ with an average vertical extent of 0.35 m. ; and an Endoderma belt with an average vertical extent of 0.25 m. The third belt is the most interesting and characteristic. This belt is dominated by members of the Chrysophyceæ which belong to newly recognised genera or species, such as *Apistonema Carteri* (n. sp.), *Chrysotila stipitata* (n. gen. and sp.), *Thallochrysis litoralis* (n. sp.) and *Gloeochrysis maritima* (n. sp.).

An important paper by J. R. Matthews (*Jour. Ecology*, XXV, 1, 1937) on the geographical relationships of the British Flora follows very closely on the lines of Salisbury's analysis of the East Anglian Flora, but extended to the entire flora of Britain. It will be particularly useful to students of geographical distribution in respect to its treatment of the Alpine and Arctic-Alpine elements.

In the same journal H. H. Allen considers the New Zealand flora from the point of view of its biological spectra. He shows that the analysis of the vegetation by Raunkiaer's system fails to give any more adequate picture of the plant climate than a careful analysis of vegetation types.

The third part of the *Proc. Univ. Durham Phil. Soc.* (Vol. X, pp. 246-351, 1937) is devoted to an account of the Natural History of the Isle of Raasay and other islands adjacent to Skye, edited by Professor Heslop-Harrison. Amongst the more notable species listed for the area are *Juncus pygmaeus* and *Juncus capitatus*, both new to the flora of Scotland, and *Cicendia pusilla*, hitherto only recorded in the British flora from the Channel Islands. Inclusive of critical segregates 603 types of "vascular" plants are here listed. The new records for V.C. 104 are numerous, viz. *Nuphar pumila*, *Erophila verna*, *Viola sylvestris*, *Arenaria trinerva*, *Hypericum dubium*, *Leers*. *Vicia angustifolia*, *Prunus avium*, *Rubus cæsius*, *Geum urbanum* G. *urbanum* x *rivale*, *Alchemilla minor*, *Agrimonia odorata*, *Sorbus rupicola*, *Myriophyllum spicatum*, *Callitriche vernalis*, *Lythrum salicaria*, *Epilobium tetragonum*, *Circeæ alpina*, *Adoxa moschatellina*, *Galium pumilum*, *Valeriana officinalis*, *Inula Helenium*, *Matricaria suaveolens*, *Arctium nemorosum*, *Vinca minor*, *Cicendia pusilla*, *Symphytum tuberosum*, *Myosotis palustris*, *Myosotis brevifolia*, *Lamium mollucellifolium*, *Orchis purpurella*, *Orchis Fuchsii*, *Polygonatum multiflorum*, *Paris quadrifolia*, *Juncus macer*, *Juncus pygmaeus*, *Juncus capitatus*, *Luzula pilosa*, *Typha latifolia*, *Sparganium simplex*, *Potamogeton pectinatus*, *Potamogeton filiformis*, *Ruppia maritima*, *Cladium mariscus*, *Carex vesicaria*, *Carex distans*, *Calamagrostis epigeios*, *Glyceria declinata*, *Bromus sterilis*, *Bromus*

commutatus, *Hymenophyllum tunbridgense*, *Asplenium septentrionale* and *Lycopodium annotinum*. The presence of Oceanic and southern species on these islands is especially noteworthy.

GENETICS.—An account of the *Allium paniculatum* group by A. Levan (*Hereditas*, XXIII, 317, 1937) deals with *A. paniculatum*, *A. pulchellum*, *A. flavum*, all of which have a diploid number of 16, *A. carinatum* with a diploid number of 24, and *A. oleraceum* with a diploid number of 32. Of these pure species the diploids in general have no bulbils, whilst plants with higher chromosome numbers usually produce bulbils. Of the *Allium carinatum* plants which were produced by breeding, individuals were obtained with 16, 17, 19, 24, and 30 chromosomes, and of these one plant with seventeen chromosomes had no bulbils and four plants with a diploid number of sixteen chromosomes produced bulbils.

ENTOMOLOGY. By H. F. BARNES, M.A., Ph.D., Rothamsted Experimental Station, Harpenden.

GENERAL ENTOMOLOGY.—A. D. Imms in his address to the Royal Entomological Society of London on January 20, 1937 (*Proc. R. Ent. Soc. Lond.*, C, 1, 1937), gave some reflections on recent developments of entomology. His remarks, which are accompanied by references, range from censuses of insects to modern types of monographs; from explanations of the fauna of unexplored lands to those on insects of the upper air; from discoveries of Permian and Triassic insects to recent trends in morphology; and from the discovery in insects (by Wigglesworth, Weed, Fraenkel and Kuhn among others) of what are comparable with endocrine organs in vertebrates to the fast disappearing distinctions between applied and purely scientific entomology.

Another address by A. D. Imms (*Trans. Soc. Brit. Ent.*, 3, 1936, 1-32) deals with the ancestry of insects. He starts by giving brief accounts of the various theories of their origin, viz. the Chilopod, the Symphylian, the Crustacean, the Trilobite, the Polychaete and the "Protaptera" theories. That in most accord with the morphological evidence is held to be the Symphylian. The earliest insects were derived from generalised Symphylla not very different from recent forms. The Protura and Collembola are side developments. The division of the Insecta into Apterygota and Pterygota is considered not to be entirely satisfactory and the following alternative grouping is suggested:

Subclass I. Oligoentomata: Collembola.

„ II. Myrientomata: Protura.

„ III. Euentomata: Thysanura and Pterygota.

This derivation of Insecta from Symphyla is fundamentally different from the recent theory of Tillyard who postulated three lines of descent of the Insecta, the Chilopoda and the progoneate Myriapoda from hexapod nauplioid ancestors (Protaptera) whose trunk comprised only four segments. The Myriapod classes, Symphyla, Diplopoda, Pauropoda and Chilopoda are in this paper shown to exhibit certain basic characters which suggest their origin from a common ancestral group of Protomyriapoda.

A. G. Richards, Jr., and A. Miller are making a critical review of the available experimental data on all phases of insect ontogeny. The first half on embryonic stages has now appeared (*J. New York Ent. Soc.*, **45**, 1937, 1-60). It deals successively with the origin of polarity and symmetry, fertilisation, cleavage and blastoderm formation, the indeterminate-determinate series, developmental centres, blastokinesis or movements of the embryo, the anlagen plan of the embryo and organ formation.

Aberrant feeding behaviour among insects is the subject of a paper by C. T. Brues (*Quly. Rev. Biol.*, **11**, 1936, 305-21). He deals with changes from phytophagous to predatory habits, from predatory to phytophagous, from phytophagous to saprophagous and from parasitic to phytophagous habits.

The food of insects and its relation to resistance of plants to insect attack has been discussed by R. H. Painter (*Amer. Nat.*, **70**, 1936, 547-66). The difference in food value of susceptible and resistant varieties is apparently chiefly in its effect on length of life, death rate, size and fecundity of the insects. The life span may also be lengthened or shortened. Examples are given from recent research of most of these effects. Thus in fecundity the corn-ear worm has a greatly reduced oviposition in moths reared on less usable food plants. These food differences are explained by specific poisons in some cases and by varying availability of food in others. There is also the possible lack of specific food materials. The importance of vitamins and the actual differences in the quantity of the right kind of food may also be important. The actual nutritive substances used by phytophagous insects in contrast to the plant parts they eat is of great importance in insect biology. Painter claims rightly that as much attention should be paid to this as has been done to humidity and temperature.

Insects of many species emerge as adults from the pupæ at a definite time of day. W. N. Scott (*Trans. R. Ent. Soc. Lond.*, **85**, 1936, 303-29) using the moth *Ephesia kühniella*, and the fruit fly *Drosophila melanogaster* to a slight extent, has made an experimental analysis of the factors governing the hour of emergence.

The diurnal rhythm of emergence of the moth showed a close relationship with the diurnal temperature rhythm, the maximum emergence always occurring shortly after the temperature begins to fall. This emergence rhythm was continued under constant-temperature room conditions but the peak was not so well defined. The rhythm was inherited to the third generation. An attempt to lengthen the periodicity was only partially successful. A periodicity of 16 hours was induced by a temperature rhythm of the same period, but it was not found possible to induce a 36-hour rhythm. Light above a certain intensity appeared to inhibit emergence.

The natural history of the isle of Raasay and adjacent islands which lie between Skye and Ross-shire (*Proc. Univ. Durham Phil. Soc.*, **10**, 1937, 246-351) contains lists of Lepidoptera, Trichoptera, Cecidomyidæ, Hymenoptera and Hemiptera-Heteroptera by J. W. Heslop-Harrison and of Psyllidæ by G. Heslop-Harrison.

When studying soil fauna it is desirable to be able quickly to separate them from the soil and in such a condition as to allow them to be identified and if necessary reared to the adult stage. Many attempts have been made in the past to devise some satisfactory method. W. R. S. Ladell (*Ann. Appl. Biol.*, **23**, 1936, 862-79) has recently described an apparatus in which the principle of flotation is used. The soil is placed in a solution of magnesium sulphate whose specific gravity (1.11) is greater than that of soil fauna. Stirring takes place and a stream of fine air bubbles is passed continuously through the mixture of soil and solution. The froth produced contains all the animals and, after passing over a sedimentation tank, is deposited on a piece of filter paper in a Buchner funnel. This method has the advantage of being rapid, fairly clean, non-toxic and efficient. On an average 85 per cent. of the soil fauna is recovered, in some cases the percentage has reached the nineties. These figures are well above those resulting from previous methods of extraction.

ORTHOPTERA.—The mechanism of respiration and its bearing on the problem of the inhalation of poison dusts has been of immediate interest to those engaged on locust control by dusting them from aeroplanes while they are actually on the wing. H. H. King and W. Rutledge some years ago (*Bull. Ent. Res.*, **23**, 1932, 65-8) suggested that the mode of action of external poison dusts was by inhalation. They argued that toxic effects should be accelerated in flying locusts owing to their higher rate of respiration as compared with resting individuals. The size of the spiracles and tracheæ of 5th instar hoppers and adults of *Locusta* and adults

of *Schistocerca* has now been determined by A. G. Hamilton (*Bull. Ent. Res.*, **28**, 1937, 53-68). Spiracles 1-4 are inspiratory in function, 5-9 are expiratory under all conditions and the function of 10 is expiratory when the locust is flying and inspiratory when it is motionless. Although dust of certain particle size (300 B.S. sieve) can enter all the spiracles, the quantity of dust in the tracheæ after 10 seconds' exposure is not regarded as sufficient to kill the locust. The action of external poisons is thought to be by direct penetration of the integument or through the nerve endings or both.

An investigation into the origin and fate of the membranes surrounding the grasshopper egg has been made by Eleanor H. Slifer (*Q.J.M.S.*, **79**, 1937, 493-506). During the last few days of incubation the tough white cuticle is rapidly digested by a hatching enzyme. By ligaturing the eggs, before the enzyme had made its appearance, at all levels from a point near the extreme anterior end to one near the extreme posterior, it was soon possible to demonstrate that the enzyme was being produced near the middle of the egg. Then it was traced to the region containing the pleuropodia or appendages of the first abdominal segment. By removing the pleuropodia it was proved that in *Melanopus differentialis* at least the pleuropodia produce the enzyme which destroys the white portion of the chitinous cuticle.

COLEOPTERA.—The seasonal trends in the relative abundance of Japanese beetle populations in the soil during the annual life cycle have been studied by H. Fox in New Jersey, U.S.A., since 1927. The results (*J. New York Ent. Soc.*, **45**, 1937, 115-26), obtained by extensive sampling in permanent grassland such as pastures and "roughs" on golf-courses, show that there is a rapid increase beginning late in June and extending throughout the summer. This results in the population reaching its maximum abundance early in September. This period coincides with the oviposition season. There is then a brief period of rapid decrease lasting till the middle of October, a long period of little or no change extending through the winter until the end of April followed by another period of rapid decrease in May and June by which time the adult emergence starts. The lack of decrease in the winter is attributed to the inhibiting effect of winter temperature on the soil-inhabiting parasites and predators. In the two periods of decrease in numbers the soil-dwelling parasites and predators appear to exert a major influence while birds and other surface-feeding animals only play a minor part.

The morphology of the larva of *Serica brunnea* has been described

by W. F. Jepson (*Bull. Ent. Res.*, **28**, 1937, 149-65), while W. Subklew (*Z. Pfl.Krankh.*, **47**, 1937, 18-34) separates larvæ of the tribes Sericini, Melolonthini, Rutelini, Dynastini and the Cetoniini chiefly on characters of the radula or raster on the anal segment. This latter paper has good illustrations. A. G. Böving, in a paper describing the larva of *Plectris aliena* Chapin (*Proc. Ent. Soc., Washington*, **38**, 1936, 169-85), gives a description of new terms applied to special structures of the epipharynx and the raster of scarabæoid larvæ. The terms used by W. P. Hayes (*Illinois Biol. Mon.*, **12**, 1929, 22-33) are given in parenthesis at the end of each of the definitions for convenience. In addition, J. H. Fidler (*J. Animal Ecology*, **5**, 1936, 333-47) has made an investigation into the relation between chafer larvæ and the physical factors of their soil habitat. In winter the temperature of the soil may become too low and the insect evades this by migration downwards. Here it reaches other limiting factors such as lack of oxygen and food. In autumn excess of soil moisture in relatively high temperatures is the limiting factor and such conditions also induce fungoid and bacterial disease. In summer the larvæ may suffer from a lack of moisture. Drought has the indirect effect of killing vegetation and so reducing the available food supply at a time when the insect's metabolism is rapid and the need for food is greatest.

The anatomy and histology of the alimentary canal of the adult *Nebria brevicollis*, a Carabid beetle which occurs in large numbers in cultivated light land, has been studied by Mary Carleton (*Trans. Soc. Brit. Ent.*, **3**, 1936, 119-28) as a preliminary to an investigation of the diet of this species.

A detailed study of *Calosoma inquisitor*, a Carabid which is well known as a destroyer of caterpillars and has been tried in biological control work in the U.S.A., Spain and Algeria, has been made by J. H. Cook (*Trans. Soc. Brit. Ent.*, **3**, 1936, 79-118).

LEPIDOPTERA.—An investigation of the seasonal availability of food plants of two species of *Heliothis* has been made by G. W. Barber (*J. Econ. Ent.*, **30**, 1937, 150-8). When the more favoured cultivated food plants are missing, the insects maintain themselves on less favoured cultivated and wild plants. The seasonal distribution of the wild food plants is such that the insects can maintain themselves on them throughout the season without using cultivated plants at all.

M. H. Haydak (*Ann. Ent. Soc. Amer.*, **29**, 1936, 581-8) has shown that wax is not an essential constituent of the food of the wax moth larvæ. The best development was attained on foods having the essential food constituents as applied to rats. The

formula suggested by this investigator consists of fine corn meal (4 parts by weight), whole wheat flour (4 parts), skim milk powder (2 parts), powdered dried yeast (1 part) and standard wheat middlings (2 parts).

The effect of winter temperature on the survival of the larvæ of the European pine shoot moth has been demonstrated to be an important environmental factor by A. S. West, Jr. (*Ann. Ent. Soc. Amer.*, **29**, 1936, 438-48). This is especially important as the feeding of the larvæ in the spring produces more noticeable damage than the autumn feeding. The development of outbreaks of this moth in Connecticut appears to be definitely correlated with the frequency of severely cold winters during the past twenty years.

HEMIPTERA.—There is an outstanding paper on the function of the corpus allatum in the growth and reproduction of *Rhodnius prolixus* by V. B. Wigglesworth (*Q.J.M.S.*, **79**, 1936, 91-121). Further evidence is brought forward to show that the corpus allatum is the source of the "moulting hormone" and the "inhibitory hormone." Some exceedingly clever experimentation demonstrates among other things that the moulting hormone from *Rhodnius* will induce moulting in bugs of the allied genus *Triatoma* and in the bed-bug *Cimex*. Likewise secretion from the corpus allatum of *Triatoma* females will cause egg development in *Rhodnius*. The moulting hormone of the nymphal stage will not cause egg development in the adult female nor will the egg-forming hormone induce moulting.

The published information on the Woolly Aphis has been reviewed by R. M. Greenslade (*Imp. Bur. Fruit Prod., Tech. Communic.*, **8**, 1936, 88 pp.). The insect and its habits in Europe and America are described and an account of the damage done is given. The effect of climate on its incidence and the control of the insect by spraying, by biological methods and by the use of resistant varieties are considered. An annotated bibliography of 600 references is appended.

Experiments have been carried out by M. A. Watson (*Phil. Trans. Roy. Soc. Lond.*, B, **22**, 457-89) on the percentage of infection obtained with the virus Hy. III in tobacco using its insect vector, *Myzus persicæ*. A maximum percentage was obtained during the winter months and a minimum in the summer months. The percentage infection increased with the number of aphids used per plant and with increased feeding time on the healthy plant. It decreased rapidly with increasing time on the infected plant from 2 minutes to 1 hour. After 1 hour it increased slightly with further increase of the feeding periods. *M. persicæ* was shown to be

capable of infecting two consecutive plants without intermediate access to an infected one, but the number of second infections decreased rapidly with increasing time on the healthy plant and is negligible after 1 hour.

The amazing number of aphids sometimes present on field crops is illustrated in a preliminary report on the resistance of alfalfa varieties to pea aphids by R. H. Painter and C. O. Grandfield (*J. Amer. Soc. Agron.*, **27**, 1935, 671-4). Samples of infestation were obtained by 20 sweeps of a 1 foot square net and the captures were measured in a graduated cylinder. A single 20 c.c. sample was found to contain 12,630 aphids. In the experiment the average number of c.c. from the different varieties varied from 22 to 127. This paper also provides evidence to show that the amount of damage is not necessarily correlated with the numbers of aphids feeding on the plant.

HYMENOPTERA.—Some years ago A. C. Kinsey was responsible for a monograph on the gall wasp genus *Cynips* which was in fact a study of the origin of species (*Indiana Univ. Studies*, **16**, 1930, 577 pp.). Now a systematic study of seventy species, chiefly from Mexico, of gall wasps new to the same genus has appeared by the same author (*Indiana Univ. Publ., Sci. Ser.*, **4**, 1936, 334 pp.). It is entitled "The Origin of Higher Categories in *Cynips*." In his previous studies Kinsey showed that species were realities in nature. Now the conclusion is reached that all the higher categories are artificial conventions useful for cataloguing biological data but hardly real in manner of origin or in their intrinsic qualities. Kinsey discards the "tree of life" as the evolutionary pattern and substitutes an infrequently dividing chain in which the oldest species may remain co-existent with all of the derived species. The most diverse ends of such a chain (the higher categories) may be united by series in which each element is a geographic or host isolate of the next in the chain. This systematic study is based on a large amount of material, 18,000 additional insects and 70,000 additional galls since his 1930 monograph, yet the author considers it far from adequate for a modern taxonomic study. In the recognition of relationships he has used insect morphology; gall structures; position of the gall on the plant; species of host on which the gall is produced; the degree to which the insect is restricted to a single species of host; the degree of similarity and difference between the successive generations; seasonal occurrence of each stage; other physiological measures of the insect, such as tropistic responses and temperature reactions; and the position of geographical range in relation to the ranges of other species.

A fifth experimental study in insect parasitism by G. Salt (*Proc. Roy. Soc. Lond.*, B, **122**, 1937, 57-75) deals with the sense (indicated to be chemical) used by *Trichogramma evanescens* in the determination of healthy hosts from those already parasitised. The parasite is able to distinguish hosts that are clean and those that have been merely walked upon by another female. If, however, parasitised hosts are washed the parasite cannot distinguish them immediately and attacks them. But as soon as its ovipositor penetrates, the parasite realises they are parasitised and usually withdraws without oviposition taking place. Salt comes to the conclusion that two different faculties perform the discrimination. One recognises an external odour and inhibits attack; the other distinguishes an internal difference and inhibits oviposition. The chemical trace left on the surface of the host is not the general body odour but a more specific smell probably produced by glands on the tarsi. It is left on the substratum on which the parasite walks. Thus the parasite sometimes mistakes healthy hosts over which other parasites have merely passed for parasitised hosts and so the former escape attack.

In an account of the biology of *Ooencyrtus johnsoni*, an endophagous parasite of the eggs of the harlequin cabbage bug (*Ann. Ent. Soc. Amer.*, **30**, 1937, 123-54), J. D. Maple discusses the rôle of the egg shell in the respiration of certain Encyrtid larvæ. Among his conclusions he states that the young larvæ of *O. johnsoni*, and probably other species of Encyrtids possessing stalked eggs and metapneustic larvæ, may utilise atmospheric air by means of the peculiar structure of the egg shell. This however has not yet been proved. Sufficient air may be derived by diffusion from the body fluids of the host through the body surface of the larva or through the æroscopic plate and thence into the spiracles.

DIPTERA.—W. Trager (*Biol. Bull.*, **71**, 1936, 343-52) has shown that the larvæ of the yellow fever mosquito are able to utilise substances in true solution. They require for normal growth a proper concentration of calcium chloride and an organic growth factor which is also a solute. This growth factor is considered by the same investigator (*J. Exp. Biol.*, **14**, 1937, 240-51) to be different from the accessory growth substance required by the larvæ of the blowfly on which R. P. Hobson has worked recently (see *SCIENCE PROGRESS*, XXX, 1936, 509).

C. W. Sabrosky (*Ann. Ent. Soc. Amer.*, **29**, 1936, 707-28) has made a synopsis of the nearctic species of the genera *Oscinella* and *Madiza* of the family Chloropidæ. These genera are a difficult group and this revision should serve as an adequate foundation

for more extended studies. The same worker has reviewed the nearctic species of the genus *Chloropisca* (*Canad. Ent.*, **68**, 1936, 170-7). The life history of only one species in this genus is at all well known, i.e. *C. glabra* whose larvæ are predaceous on root aphids and are especially imported as predators on the sugar beet root aphid, *Pemphigus betæ*.

Flies of the genus *Rhagoletes*, especially the apple, hawthorn and blackberry forms of *R. pomonella*, have been studied by A. D. Pickett (*Canad. J. Res.*, **15**, Sec. D, 1937, 53-75). He has come to the conclusion that only one distinct species is involved and that there is not sufficient evidence on the basis of biological or morphological interpretations or both to prove the existence of more than a single species. He regards *R. pomonella* as an oligophagous species in which the host selection principle has become highly developed. The host selection principle was first suggested by Hopkins and is as follows—an insect species which breeds on two or more hosts will prefer to continue to breed in the host to which it has become adapted.

R. P. Hobson has been continuing his sheep blowfly investigations. His third study (*Ann. Appl. Biol.*, **23**, 1936, 845-51) deals with the chemotropic responses of *Lucilia sericata* and shows that sheep vary considerably in their attractiveness. This can be measured with solutions of indole and ammonium carbonate. He has devised a technique for testing repellents. His fourth study (*loc. cit.*, 852-61) is on the chemistry of the fleece with reference to the susceptibility of sheep to attack. A. C. Evans (*Trans. R. Ent. Soc. Lond.*, **85**, 1936, 363-77) has written a review of the physiology of *L. sericata*.

The breeding media of some common flies including forms such as the house-fly and stable-fly have been re-investigated by M. Thomsen and O. Hammer (*Bull. Ent. Res.*, **27**, 1936, 559-87). Observations showed that on Danish farms in the summer the house-fly breeds mostly in fresh pig-dung deposited in manure pits, next frequently in the bedding of calf stables and next in horse-boxes and pig-sties. Horse manure in manure-pits was of minor importance as a breeding ground under rural conditions, chiefly perhaps because in the summer the horses are generally out and little manure is deposited in the pits. Experiments showed that there was no essential difference between horse-manure and pig-dung in their power to attract ovipositing house-flies, calf-dung was far less attractive and no eggs were laid in pure cow-dung. As regards the stable-fly, it breeds chiefly in the bedding of calf-boxes and was found only rarely in horse manure, pig-dung and cow-dung. Experi-

mental evidence showed that this fly preferred oviposition in horse manure and calf-dung, only a few eggs being laid in pig- and cow-dung.

An interesting development in the use of sera and antisera is illustrated in a paper by C. B. Symes and J. P. McMahon (*Bull. Ent. Res.*, **28**, 1937, 31-42). In this they have described experiments from which they have found, by means of the precipitin test, the main food of hosts of *Glossina swynnertoni* in a district of Tanganyika to be one or more Bovids, giraffe and pig.

The tsetse fly problem in Africa is at once urgent and important. In tropical Africa four and a half million square miles are under infestation by the fly. In other words there is a band of infested country nearly 2,000 miles wide extending across Africa. In the greater part of this area cattle cannot be kept and sleeping sickness still takes its toll of the human population despite modern treatment. Two-thirds of Tanganyika Territory are already under fly and new areas are being steadily invaded. The director of tsetse research in this country has written an account of the present situation entitled "The Tsetse flies of East Africa: A First Study of their Ecology, with a View to their Control" (*Trans. R. Ent. Soc. Lond.*, **84**, 1936, xxxvi + 579 pp., 7 maps and 22 plates). This covers the work of the Tsetse Research Department, T.T., from the beginning of 1931 to the end of 1934. In addition, information from outside is included in order to bring up to date our knowledge of East African tsetse flies. Apparently the lack of money prevents man getting the upper hand. Reclamation of tsetse areas is possible and could be carried out at a faster rate than new territory is being invaded by the fly if only the necessary support were available.

ARCHAEOLOGY. By E. N. FALLAIZE, B.A.

By a happy inspiration the Academy of Natural Sciences of Philadelphia celebrated the one hundred and twenty-fifth anniversary of its foundation by an International Symposium on Early Man, which was held in Philadelphia from March 17 to 20. Europe, Asia, America, and Africa in a lesser degree were represented in the communications which were presented, while the problems of the chronology of early man as present in each quarter of the globe were well thrashed out in a round-table discussion at the close of each day's proceedings. The results of the symposium as a whole were summed up at the close in a survey by Dr. G. Grant McCurdy, who pointed to the sum of the discoveries in prehistoric archaeology of the last forty years in support of the contention that the advances in this science in range and importance could well take their place

with those of other branches of scientific investigation during that period.

In interest, if not in number, the communications dealing with early man in Asia must undoubtedly be awarded first place. Not unnaturally they gained a predominant share of attention, owing in part to the fact that the discovery of three new skulls of Peking man in the preceding November–December was fresh in mind, and in part to the importance of the report on early man in Palestine by Sir Arthur Keith and Mr. Th. McCown. The perennial problem of the antiquity of man in America and his relation to the modern Indian population gained an added significance in the light of recent investigations in Alaska and the South-Western states, as well as from the efforts which are now being made to bring the geological and palæontological evidence into closer relation with the facts of archæology.

EARLY MAN IN ASIA.—In the communications to the symposium dealing with early man in Asia, Dr. Hellmut de Terra, the field director of the expedition, surveys the results of the Yale University Expedition to the Himalayan foothills of northern India. He gives an account of the discoveries in the Siwalik Hills of the remains of fossil apes, which had been the primary object of the expedition—discoveries which have thrown much light on their relation, more especially the relation of *Dryopithecus*, to the early line of descent of man—and then refers to the effect of physiographical changes, of which evidence had been found in this area, on the problem of the development of man in Asia. He also describes the records of early Stone Age cultures, which had been found by the expedition. As regards the effect of geographical and climatic change, Dr. de Terra has arrived at the conclusion that in late Tertiary times a shifting of the tropical belt from north to south had caused a migration of the mammals of India to South-East Asia. He also holds it to have been a major factor in human evolution so far as Asia was concerned. As regards the Stone Age evidence, he finds that a great expansion of the old Palæolithic races had taken place from southern India to the Siwalik Hills some time in the Middle Pleistocene, shortly after the Himalayan glaciers had retreated from their second major advance, while towards the close of the Ice Age another stone-using people had invaded the lower Indus valley, settling in the area which recent excavation had shown to be the seat of a great civilisation in later ages. The Indus valley, like other large drainage areas, has thus a long tradition of human prehistory.

An appropriate pendant to Dr. Hellmut de Terra's conclusion

as to the effect of climatic change on man's development in Asia was afforded by a communication from P. Teilhard de Chardin, who argued for what would appear to be a similar change with analogous consequences in China. As the result of a vast upheaval in the east of Asia, he maintained, the lakes of northern China had dried up, their sediment had been sharply tilted, and fans of red clay had spread over the slopes, this change being accompanied or followed by a migration or extinction of the sub-tropical fauna and flora. An immigration of animals, such as the deer, from the north-west and from the south had then taken place. Contemporary with this migration and also probably coming from the south, man had appeared. The author anticipated that correlation of the forms entering China from the north-west with those of Europe would make it possible to elaborate a system of chronology for China.

A further communication dealing with early man in China was an important survey of the Stone Age industries by Mr. W. C. Pei, by whom the first skull of Peking man was discovered at Choukoutien in 1929. Mr. Pei classifies the main palæolithic industries of China into four stages, but two earlier forms have been recognised by the Abbé Breuil—the Nihowan and "Locality 13." Of these the earlier is the Nihowan. According to the Abbé a piece of worked stone and some worked bones from Nihowan are the oldest indication of human handiwork in China. They are of Upper Pliocene age and the equivalent of Villafranchian in Europe. "Locality 13" is represented by a chert implement of undoubtedly human origin, corresponding to the Abbevillean in France and belonging to an early phase of the Lower Pleistocene. The true stone industry of China, in Mr. Pei's view, begins with *Sinanthropus*, the characteristic industry of Peking man. It also is compared with the Abbevillean of Europe and attributed to the Lower Pleistocene, although it seems undoubtedly to be later than "Locality 13." From near the locus of *Sinanthropus* comes the industry known as "Locality 15." In age it appears to be later than *Sinanthropus* and to belong to the Early Middle Pleistocene. It corresponds to the late Lower Palæolithic of Europe. Following this is the Ordos industry, a contemporary in part of the Chinese loess; it may be attributed to the Late Middle Pleistocene. Lastly, there is the Upper Palæolithic of China, represented by the Choukoutien Upper Cave industry, which corresponds to the European Aurignacian, Solutrean and Magdalenian.

Important and interesting communications, such as Dr. G. H. R. Koenigswald's "Man's Geologic Record in Java," Miss Garrod's "The Near East as a Gateway of Prehistoric Human Migration,"

and Professor V. Gordon Childe's "The North Eurasian Forest Cultures in the Mesolithic and Neolithic Phases" must be passed over to note briefly some of the communications which dealt with early man in America.

EARLY MAN IN AMERICA.—For some time it has been recognised that the most insistent problem in American prehistory is the correlation of the data of geology, palæontology and archæology with a view to the question of chronology. Mere mention, therefore, in passing, of Dr. Aleš Hrdlička's restatement of his view that the skeletal remains of early man found in America do not point to a high antiquity, nor differ in essentials from the physical characters of the modern Indian, must suffice in order to deal more fully with other aspects. The geological basis of the archæological problem was considered by Dr. Paul McClintock in a summary outline of the glacial stratigraphy of North America as understood at present. He divides the Pleistocene into four major interglacial episodes—the Nebraskan, Kansan, Illinoian and Wisconsin glaciations and the Aftonian, Yarmouth, and Sangamon interglacials. The three earlier glaciations may have been complex in nature, but knowledge is too scant to attempt to fix details. The best known is the Wisconsin or last episode, of which the drift lies on the surface. It is divided into five well-recognised stages, which are separated from one another by ice recession and accumulation of outwash, loess and forest-bed deposits, while the major interglacial episodes are marked by erosion, deep weathering and the accumulation of forest beds and loess sheets.

The geological and palæontological problem, as it presents itself in Nebraska, where it is of importance in relation to the "Folsom stone points" and "Folsom man," was considered by Professor Erwin H. Barbour and Dr. Bertrand C. Schultz, on evidence collected by field parties from the Nebraska Museum, working since 1929. A sequence has now been fairly well established for Nebraska. A new Lower Pleistocene fauna was discovered near Broadwater, Morrill County, in 1936, while Hay Springs, Sheridan County, has provided a mammalian assemblage of the Mid-Pleistocene. The authors pointed out, however, that the Late Pleistocene and recent fauna offer some of the most complex problems; and the time of extinction of many of the animals and the appearance of associated artefacts has made this period even more involved. River terraces in certain localities have aided in determining the ages and relationships of various faunas as well as of artefact horizons. In one low 15–20 foot terrace artefacts have been found, but no extinct forms have been reported from this, nor in the contemporaneous artefact levels

of Signal Butte, Scottsbluff County, where, however, an older or 40-foot terrace was found to contain mammalian remains, with artefacts at its base. Further researches up to the present are without decisive results.

Dr. Elias H. Sellards, of the University of Texas, who reconsidered in the light of present-day knowledge the finds from Vero, Florida, in which in 1916 human materials were found in association with animal and plant fossils, was of the opinion that the view formerly held that the elephant, tapir, sloth and associated species became extinct before the close of the Pleistocene was no longer to be regarded as safe, and concluded that some, and possibly several, of these now extinct species may have continued to exist well into recent times.

Virtually an identical inference was drawn from a consideration of the problems of the interrelation of the Pleistocene mammals of North America and Eurasia and their bearing on the problem of early man in America by Dr. Elwin H. Colbert of the American Museum of Natural History. A study of the modern mammals shows that the faunas of North America and Eurasia are closely related and this relation was equally close in Pleistocene times, when for a major portion of the period the two continental areas were connected by a land bridge from Siberia to Alaska, which afforded a wide corridor for intermigration. At the same time there were differences, for which explanations can be offered in most, though not in all cases. The beginning of the Pleistocene was marked by the almost worldwide spread of certain mammals, such as the horse, mammoth, camel and the cattle. The end of the Pleistocene would seem to have been marked by the extinction of certain forms, such as the mammoth, the woolly rhinoceros of Eurasia, and the mastodon, the camel, the ground sloths, and the horse in America; but there is a great deal of evidence to indicate that certain "typical" Pleistocene mammals persisted beyond the Pleistocene into recent times. The frozen cadavers of mammoth in Siberia and Alaska would seem to indicate that they lived only a few thousand years ago. In North America there is good ground for supporting the contention that the mammoth, camel, horse, extinct bison, and the ground sloths persisted until relatively recent times. In Eurasia man is associated with Pleistocene mammals throughout the duration of the period. In North America, on the other hand, man is a relatively recent immigrant from the old world; but the explorations of the last two decades would seem to indicate that man reached the Western hemisphere before many of the typical mammals had become extinct. There is definite

evidence of his association with mammoth, camel, horse and ground sloth. The Pleistocene age of man in North America is thus still a matter of interpretation of what marked the end of the Pleistocene period in America.

A small group of communications dealt with what might be termed "collateral evidence" in archæological studies, and is of special interest to European archæologists, where these methods of study have been developed. One of these is the method of pollen analysis, which Professor Paul B. Sears of the University of Oklahoma considered as a possibility in North American archæology. Although peat, the European medium, is not formed in the southwest, the Oklahoma laboratory has found that the sediments from the Arizona canyons contain well-preserved pollen which might be correlated with periods of climatic change, as shown by pollen analysis elsewhere.

The evidence of Pleistocene molluscs as indicators of time and ecological conditions was considered by Dr. Frank Collins Baker, of the University of Illinois Museum, who dealt with land and fresh-water forms, and Dr. Horace G. Richards, of the New Jersey State Museum, who dealt with the marine forms. Dr. Baker pointed out that from the Pleistocene deposits within englaciated territory in North America 370 species of mollusca had been listed, of which 29, or 7·8 per cent., have become extinct. Dr. Richards, who has studied fossil localities from Hudson Bay to the Caribbean Sea, finds that the Pleistocene deposits north of New England indicate a cold sea and probably a Late Wisconsin age, whereas a few places in New England, such as Nantucket, possess a fauna which suggests a somewhat milder climate, possibly of interglacial age. South of the terminal moraine the Pleistocene marine deposits indicate a climate slightly milder than the present, and may belong to a last major interglacial stage.

In this connection it is of interest to direct attention to a further development of the application of palæontological and zoogeographical method to the problems of archæology, on which Mr. P. Ulyott of the Department of Zoology, Cambridge, has been working ("A Note on the Zoogeographical History of North-western Europe" *Proc. Prehist. Soc.*, 2, 1). He has here opened up a new line of evidence for dating the severance of Britain and the Continent and the subsidiary questions which arise therefrom. Mr. Ulyott examines the geographical distribution of certain types of flat-worms (planetarians) belonging to the same group and living in fresh water, but adapted to different temperature ranges. Briefly his conclusion is that the distribution of these types suggests that Britain must

have separated from the Continent after the average summer temperature had exceeded 12° C. but before it reached more than 16° C. As the curve of mean summer temperature during post-glacial times is known fairly accurately, it is, therefore, possible to say that the breaking of the land surface across which the flat-worms migrated in fresh water from the Continent to Britain must have occurred during the Boreal period, but before its later stage, when the temperature curve rose to its maximum during post-glacial times.

Questions of land elevation and submergence are also brought under consideration in an important investigation, which has been carried out by a sub-committee of the Fenland Research Association under the Chairmanship of Mr. S. H. Warren (*Proc. Prehist. Soc.*, 2, 1) on the submerged land surface of the Essex coast. The report of the sub-committee deals with the character of the land surface, pollen analysis, pottery and flint implements, and also discusses the relation of this area to the East Anglian fenland. The archæological sites investigated are situated at Lion Point, Clacton, Mill Bay, Dovercourt, and Stone Point, Walton-on-Naze, where surface settlements, pit dwellings, cooking holes and hearth sites were examined. The earliest trace of human habitation was Mesolithic, followed by Neolithic A and Neolithic B. The latest dateable material is a few beaker B sherds, but no beaker A or Bronze Age cord ware was found.

THE INDUS VALLEY CIVILISATION.—Further excavations in the Indus Valley have thrown additional light on the early civilisation of Northern India, of which the first indications were found at Mohenjo-daro and Harappa. An expedition of the American School of Indic and Iranian Studies, supported by the Boston Museum of Fine Arts working under the field direction of Dr. E. Mackay, began in October 1935 the excavation of a site at Chanhu-daro, east of the river Indus and eighty miles south-west of Mohenjo-daro in the Province of Sind. This site was chosen in the hope that it might throw light on the civilisation of the period preceding that already known at Mohenjo-daro and also on the dark period which follows, before the entry of the Aryan-speaking peoples into India about 1500 B.C. The site consists of two large mounds and one small mound. These in ancient times had constituted a single city site, but it had been cut through by flood water from the Indus, a disaster which had led to the city being abandoned. As Mohenjo-daro is also known to have suffered from the effects of flooding, Dr. Mackay suggests that this may have been the cause of the downfall of this great civilisation. As regards the main objective

of the excavation, at present the lowest levels reached appear to be somewhat earlier than the strata immediately above water level at Mohenjo-daro ; but there is no culture between the base mound level and subsoil water, which was reached at twenty-five feet below plain level. Evidence was found of five occupations of the Harappa civilisation (as it is now called) ; while above the last Harappa level was found an occupation at about 2000 B.C. of a small community of unknown origin, the Jhukar, living in houses of matting or mud, and, on their disappearance, another small community of a primitive form of culture already known as the Jhangar, from a site of that name in Sind.

The site of Chanhu-daro is remarkable for its careful and elaborate system of drainage, its rich store of metal work in copper and bronze, its pottery, and its local manufacture of beads. An account of the results of the first season's excavations is given by Dr. Mackay in *J.R. Soc. Arts*, 75, No. 4405.

NOTES

Huxley Memorial Lecture, 1937 (A. B.)

The Huxley Memorial Lecture was delivered in the Huxley Building of the Imperial College by Sir Thomas Holland on Tuesday, May 4. He took as his subject "The Permanence of Oceanic Basins and Continental Masses."

Sir Thomas outlined the evolution of naturalists' ideas on a problem which, long before Darwin framed his "laws of descent," had erected itself on the difficulties raised by the geographical distribution of life-forms—particularly those which had *apparently* migrated across "impassable" oceanic barriers or negotiated "annihilative" climatic and physiographical obstacles.

Lyell, in his *Principles*, made no reference to the problem; nor did he discuss it until, many years later, he had reluctantly accepted Darwin's views.

Forbes (1846) had realised the necessity for assuming considerable change between oceanic and continental conditions. Dana (1856), on the other hand, decided that the sites of the present continents and oceans must have been defined in early geological times.

When Darwin (in 1859) propounded the doctrine that each species had proceeded from a single birthplace, he had to face the problem of accounting for species which had achieved *apparently* impossible feats of migration. Rejecting Forbes' views, he followed Dana in assuming the permanence of oceans and continents, and stressed numerous "casual and unexpected means of transport" which had come under his own observation. Only once (in 1870) did Huxley discuss this problem. In order to account for the fauna migrant into Hindustan during Miocene times, he assumed a land-connection between the Deccan and Central and South Africa. For the concordances between the Miocene beds of Europe and North America he again required "continuity of land-mass," without (be it noted) actual rise of land *across* an oceanic abyss; connection via the continental shelf could conceivably have met

this requirement. On the other hand, for pre-Tertiary migration from continent to continent, he assumed a "vast alteration" of world geography—considerable vertical movement and "incessant change" of coastal areas and connecting channels; but he still insisted on a general permanency of major oceanic and continental units.

This deference to Genesis and the Mosaic cosmogony was first challenged (in 1855) by Blandford when he recognised the implications of the Gondwana system of India. By the year 1891 he had correlated the Gondwana facies with similar formations in South America, South Africa and Australia, and to him no explanation other than "foundering" was conceivable. On Blandford's conclusions Suess (1855) based his concept of an ancient Gondwanaland, which palæogeographers have come to accept with conviction.

Blandford's conclusions received further support five years ago from Schuchert, who nevertheless betrays the traditional bias towards Dana's views by naïvely pleading for "a *smaller* Gondwanaland," which would be "easier to sink." The same lingering loyalty to these views seems to underlie Bailey Willis's recent (1931) conception of "Isthmian Links" as cordillera-like ridges connecting *permanent* continents.

The modern phase opened with the advent of the Wegener hypothesis. Outlining the distributional problems this hypothesis claimed to solve, Sir Thomas commended its constructive ideas to naturalists generally, urging, however, that judgment should be withheld pending the accumulation of data adequate to assess the validity of the hypothesis. In the meantime, a notable contribution to the case has recently been made by du Toit, who has compared the formations on opposite sides of the South Atlantic and established concordances which can be explained only by assuming that South Africa and South America are 2,000–3,000 miles farther apart than they were at the close of Mesozoic times.

We can confidently look to the future to supply the balance of observational data needed—facts of such a concrete character that mathematical postulates could neither challenge, nor modify, nor override them. These facts must be accumulated in the only way acceptable to naturalists—the Darwin and Blandford way.

Investigations on Salmon and Sea Trout (W. L. C.)

In continuation of the series of investigations carried out by the Fishery Board for Scotland, there have appeared three papers on Salmon¹ and three on Sea Trout.²

The war put an end to the coastal marking of salmon, and now at length this has been resumed at Loch Inchard, on the west coast, a short distance south of Cape Wrath.

After analysing the well-recognised effects of an on-shore, as compared with an off-shore, wind and referring to experiments with different kinds of marks employed, an attempt is made in the first paper to draw conclusions about Routes of Migration. In the scale examinations of recent years it has become possible to identify different types of parr growth and to identify these with different rivers. When scales are taken from salmon caught in the sea, this information supports the view already arrived at that fish at any part of the coast are not of local origin but are drawn from widely separated rivers, and may be returning to many different rivers. Recaptures always show a scattering of the marked fish. From Loch Inchard there is a scattering to both sides of the country, and an interesting map is given showing the points of recapture and the interval of time. Mr. Menzies suggests that the fish found at Loch Inchard may come from a feeding-ground away north or north-west of the mainland. From Norwegian marking by Dahl we have instances of fish recaptured at Montrose and elsewhere on the east coast. One of the Loch Inchard marked fish has now been recaptured not far from Bergen, one as far south as Whitby, another on the west side as far as the Isle of Mull, while three went to the Outer Hebrides.

The second paper was published in 1935 and is No. 5 of the series. It is based on the examination of 2,329 samples of scales. At the same time the Tay Salmon Fisheries Co. have supplied, confidentially, the percentages of their catch each month

¹ *The Movements of Salmon Marked in the Sea. I. The North-west Coast of Scotland in 1936.* By W. J. M. Menzies, F.R.S.E. (Edinburgh: H.M. Stationery Office, 1937. 2s. net); *Salmon of the River Tay, 1934.* By P. R. C. Macfarlane, B.Sc. (Edinburgh: H.M. Stationery Office, 1935. 1s. 3d. net); *Salmon of the River Nith, 1935.* By P. R. C. Macfarlane, B.Sc. (Edinburgh: H.M. Stationery Office, 1936. 9d. net.)

² *Sea Trout of the Kyle of Sutherland District, 1934-35.* By G. Herbert Nall, M.A., F.R.M.S. (Edinburgh: H.M. Stationery Office, 1936. 2s. net); *Notes on Sea Trout from the Dee Tidal Nets, Aberdeen, 1935.* By G. Herbert Nall, M.A., F.R.M.S. (Edinburgh: H.M. Stationery Office, 1936. 1s. 6d. net); *Sea Trout of the Laxford System (Loch Stack and Loch More).* By G. Herbert Nall, M.A., F.R.M.S. (Edinburgh: H.M. Stationery Office, 1936. 1s. 6d. net.)

of the season, and the particulars have made it possible to correlate the results of the scale examination. In a river well known for its spring fishing, it may be surprising to learn that the predominant age group is the small summer (2 + winters) fish, and that the grilse approximate to this group in numbers. The large spring fish formed only 9 per cent. of the total, but in a previous examination made in 1930 they were found to be 21.7 of the total. The small spring fish (2 winters) are more numerous than the large in both collections. The grilse of the Tay have always been known as large. They average $6\frac{1}{2}$ lb., the maximum weight being 11 lb., and the minimum 3 lb. It is possible, however, to find lighter weights in certain years. As in other districts the bulk of the large spring fish come into the river in the early part of the season, after which their numbers diminish rapidly.

The third also is a paper based on scale examination, and 801 samples of scales were obtained for examination. In this river the small spring fish were found to be the chief group, the grilse being almost as numerous. Large spring fish formed only 6.4 per cent. of the whole, while large summer fish (3 + winters) were 0.1. Moreover, the peak period of the season was in March (64.7 of the season), a result which might well have an influence upon the alteration of the annual close time. The same habit of the large spring fish already noted in the case of the Tay obtains in the Nith also, but in the Solway district the grilse are relatively light in weight. A point of interest is that the calculated lengths of the parr and smolts show a greater measurement than in any other river in Scotland, and the increment added in the sea is also in corresponding degree.

Mr. Nall has studied the Sea Trout of all the chief rivers in Scotland, and in the first paper, although the Kyle of Sutherland is not an important district for this fish, he gives four tables in which comparison is made between fully twenty districts. It is in such comparisons that a comprehensive view can be obtained concerning the age at time of the first seaward migration, the lengths of the smolts, growth in the sea, and age at maturity. Thanks to Mr. Nall's long series of scale examinations we are now in a position to understand this plastic species as never before. We learn that there is a spring run in the Spey, Tay, and Tweed, Beaulieu, and certain rivers of the West, and that there is no such run in the Kyle; that in the Solway the migrating sea trout smolts are of shorter length than elsewhere—a singular fact in view of Mr. Macfarlane's discovery, noted above, that the salmon smolts are longer than in other localities. The sea trout in the Aberdeenshire Dee tidal waters are very numerous but are not

to any great extent belonging to the Dee district, because the Dee estuary is a favourite place for sea trout from other rivers congregating. Some 84 per cent. of them are maiden fish in their second summer migration. In the case of the Laxford district in which the famous Loch Stack is situated, perhaps the finest sea trout fishing loch in all Scotland, the fish are large yet they are of slow growth. Over 3,000 samples in the Dee showed that the great majority were under 2 lb. in weight. In the Laxford, 3-lb. fish are common, as in the Ewe and Loch Maree district, while fish up to 10 lb. were obtained—a single fish of 12½ years. Another feature is that the smolts migrate chiefly when 3 years old, in accordance with the ascertained facts about geographical latitude. In Loch Stack it is usual to throw back all sea trout under a pound in weight, and the supervision of the excellent spawning areas, etc. is sufficient to preserve a large stock in spite of the slow rate of growth in the sea.

Could Diluvial Man Count ? (G. D.)

Some recent discoveries by Dr. Karel Absolon, curator of the Moravian Museum at Brno, Czechoslovakia, and an authority on Palæontology, suggest that the mammoth hunters of 20,000 years ago could count. In the course of excavations at Věstonice in South Moravia (on the route from Warsaw to Vienna known to have been followed by prehistoric animals in their winter migrations) remains of settlements have been unearthed and a number of plastic and carved figures have come to light. They mostly consist of representations of animals, either heads of bears, lions, horses and others hard to identify, or the torsos of these creatures. Some of the heads lack definite form or have had the ears, eyes or nose deliberately omitted. They were found associated with mammoth teeth and skulls and some of these have been carved into clear representations of animals, but perhaps the most significant find is that of marked bones of wild horses and wolves.

Horse bones had been made into crude long-pointed pins with markings as though used for counting. A wolf's leg-bone also had 55 clear and regular parallel lines, the twenty-fifth and twenty-sixth being twice as long as the rest and there seems evidence that these contemporaries of the Cro-Magnonians of France were not only able to count but could count on a system of fives derived presumably from the fingers of the hand.

The most important plastic object that has come to light through Dr. Absolon's excavations is the so-called Věstonice Venus. This model of a pre-historic beauty is about 6 inches high and the artist

must have devoted much thought to its construction and the details of the limbs and features. Visitors to the Brno museum will find there only a plaster cast, for the valuable and unique original is kept in the vaults of a bank in the vicinity and can only be seen under special circumstances.

The Future of Canadian Mining (G. W. T.)

A well-illustrated brochure with the above title has been published by the Canadian Government (Ottawa: 1936, 83 pp.). It consists of verbatim reports of twelve radio talks on various aspects of Canadian mining which were delivered between January and April, 1936. The introductory talk was given by the Hon. T. A. Crerar, Minister of Mines, on "The Development of Canada's Mineral Resources." In this, Mr. Crerar says that he is introducing a series of *ten* talks, and his name appears on the title-page apparently as the author of the whole series, yet there is internal evidence that at least some of the talks were delivered by other voices. This interesting little volume provides an excellent conspectus of the present state and future prospects of Canadian mining. The following eleven chapter titles illustrate very strikingly the scope and aim of the work: "The Lure of Gold pushes back Canada's Northern Frontiers"; "Northern Mining Forges New Link between Eastern and Western Canada"; "The Nature and Distribution of Canada's Gold"; "The Rôle of the Mining Industry in Creating Employment"; "The New Traffic that Mines are Creating for Canadian Railways"; "The Industrial Metals in Canada's Mining Industry"; "Metal Mining in British Columbia and Yukon"; "Canada's Mineral Industry in its Relation to the National Welfare"; "The International Importance of the Canadian Mineral Industry"; "The Non-metallic Minerals in Canada's Mining Industry"; and "An Epitome of the Mining Industry in Canada." In the talk on the international importance of the Canadian mineral industry it is clearly shown how the decline in agricultural production, especially wheat, caused by the recent collapse of international markets, has been compensated by the rapid growth of exports of gold and non-ferrous metals in the last few years. It has been fortunate for Canada that she is blessed with more than her share of the world's mineral wealth, and an abundance of water power with which to develop it.

Miscellanea.

The Coronation honours list published on May 11 included the following names: *Baron*: Sir John Cadman, chairman, Anglo-

Iranian Oil Company. *K.C.B.* : Prof. E. Mellanby, secretary, Medical Research Council. *K.C.M.G.* : Prof. A. P. W. Thomas, emeritus professor of botany, zoology and geology, University College, Auckland. *Knights Bachelor* : Prof. R. W. Chapman, professor of engineering, University of Adelaide ; Brigadier H. J. Couchman, surveyor-general of India ; P. Kelland, chief veterinary officer, Ministry of Agriculture and Fisheries ; Col. A. Olver, adviser in animal husbandry, Imperial Council of Agricultural Research ; Dr. R. H. Pickard, director of the British Cotton Industry Research Association ; Prof. D'Arcy W. Thompson, professor of natural history, University of St. Andrews. *C.H.* : Prof. C. T. R. Wilson. *C.B.* : Major-General H. M. Perry, professor of pathology, Royal Army Medical College ; Dr. D. R. Pye, director of scientific research, Air Ministry ; C. W. Wright, director of scientific research, Admiralty. *C.M.G.* : A. J. Findlay, director of agriculture, Zanzibar ; C. F. M. Swynnerton, director of tsetse research, Tanganyika Territory. *C.I.E.* : Lieut.-Col. Clive Newcomb, chemical examiner to the Government of Madras and principal, Medical College, Madras. *C.B.E.* : Prof. A. L. Bowley, emeritus professor of statistics, University of London ; Dr. A. D. Crow, director of ballistics research, Royal Arsenal, Woolwich ; Col. J. Heatly-Spencer, professor of tropical medicine, Royal Army Medical College. *O.B.E.* : H. N. Linstead, secretary, Pharmaceutical Society of Great Britain ; H. W. Simmonds, entomologist, Fiji ; Dr. J. M. Stagg, senior technical officer, Meteorological Officer. *I.S.O.* : A. More, deputy Government chemist.

This year the names of the new fellows of the Royal Society were not announced until after their election by the Society as a whole. The election took place at the meeting held on May 6 and the list is as follows : J. D. Bernal, lecturer in crystallography, University of Cambridge ; Prof. A. C. Chibnall, professor of biochemistry, Imperial College of Science and Technology ; Prof. G. R. Clemo, professor of chemistry, Armstrong College ; Dr. A. N. Drury, lecturer in pathology, University of Cambridge ; Prof. H. Munro Fox, professor of zoology, University of Birmingham ; Prof. W. E. Garner, professor of physical chemistry, University of Bristol ; Dr. S. Goldstein, lecturer in mathematics, University of Cambridge ; Dr. P. Hartley, director of biological standards, National Institute for Medical Research ; Prof. H. L. Hawkins, professor of geology, University of Reading ; Rev. J. E. Holloway, lecturer in botany, University of Otago ; Dr. W. Hume-Rothery, Warren research fellow of the Royal Society ; Dr. T. G. Mason,

Cotton Research Station, Trinidad ; J. Reid Moir, archæologist ; Dr. M. L. E. Oliphant, assistant-director of research, Cavendish Laboratory, Cambridge ; Dr. C. F. A. Pantin, lecturer in zoology, University of Cambridge ; Dr. D. R. Pye, deputy director of scientific research, Air Ministry ; Dr. E. C. Stoner, reader in physics, University of Leeds.

H.M. the King has approved the award of the Founder's medal of the Royal Geographical Society to Col. C. G. Lewis for his surveys in Iraq, Syria and elsewhere, and the award of the Patron's medal to Mr. Lincoln Ellsworth for his contributions to the aerial exploration of Polar regions.

Sir Frederick Gowland Hopkins has been awarded the Harben gold medal of the Royal Institute of Public Health.

The Council of the Royal Anthropological Society has awarded the Wellcome gold medal to Dr. C. K. Meek for his work in Nigeria and the Rivers Memorial medal to Dr. E. C. Evans-Pritchard for his work in Kenya and the Sudan.

The Gunning Victoria Jubilee prize for the period 1932-36 has been awarded by the Royal Society of Edinburgh to Prof. C. G. Darwin for his contributions to mathematical physics.

Prof. G. G. Henderson, regius professor of chemistry in the University of Glasgow, has been awarded the medal of the Society of Chemical Industry.

We have noted with great regret the announcements during the past quarter of the death of the following men of science : Prof. A. W. Borthwick of Aberdeen, forester ; Dr. A. H. Church, F.R.S., of Oxford, botanist ; Dr. W. H. Collins, formerly director of the Canadian Geological Survey ; Sir James Currie, chairman of the governors of the Imperial College of Tropical Agriculture, Trinidad ; Dr. W. M. Davies, of Bangor, entomologist ; A. Davy, director of the Western Electrical Instrument Co. ; Mr. A. Gallenkamp, founder of the firm bearing his name ; Dr. S. F. Grace, of Liverpool, mathematician ; Sir Capel Holden, F.R.S., engineer ; Prof. Paul Janet, of Paris, physicist ; Sir Albert Kitson, formerly director of the Gold Coast Geological Survey ; Prof. D. A. Low, Queen Mary College, engineer ; Dr. F. S. Macaulay, F.R.S., mathematician ; Sir Thomas Mottram, F.R.S., formerly H.M. Inspector of Mines ; Prof. A. Pictet, of Geneva, organic chemist ; Prof. F. P. F. Ransom, of London, pharmacologist ; Prof. J. O. Stieglitz of Chicago, organic chemist ; Mr. W. Taylor, F.R.S., director of Messrs. Taylor, Taylor & Hobson ; Dr. Elihu

Thomson, electrical engineer ; Prof. M. C. W. Weber, For. Mem. R.S., of Amsterdam, zoologist ; Prof. S. Young, F.R.S., chemist.

Sir Henry Tizard has been elected to be a member of the Board of Trustees of the British Museum.

Prof. W. L. Bragg, Langworthy professor of physics in the University of Manchester, has been appointed to succeed the late Sir Joseph Petavel as director of the National Physical Laboratory.

It is announced that the Science Museum at South Kensington will remain open on Thursdays, Fridays and Saturdays until 8 p.m., the closing time on other days being 6 p.m. as customary on all days since October, 1931. This is a resumption of pre-war practice and it is hoped that it will receive support from the general public, as it certainly will from serious students whose work makes it impossible for them to use the collections during the daytime.

The Mineral Resources Department of the Imperial Institute has issued a monograph on *Strontium Minerals* (pp. 33, 1s. 6d.) which contains an up-to-date account of their occurrence, their treatment and their uses. The world's most important sources are the celestite (strontium sulphate) deposits near Bristol and the deposits of strontium carbonate in Westphalia. The English celestite has dominated the market, the bulk of the supply being sent to Germany for the manufacture of strontium compounds, some of which returned for use in the United Kingdom. They have a variety of uses especially in the beet-sugar industry ; in the manufacture of fireworks, flares, torches and signals ; as fillers in the seals of electric batteries, in water-paint distempers, asphalt surfacing material and rubber ; as "cleansers" for removing sulphur and phosphorus from special steels ; as precipitants in the purification of caustic soda ; in certain refrigerators ; and in the chemical, pharmaceutical and ceramic industries. Certain of the salts are regarded as essential war materials, particularly for the manufacture of tracer-bullets and red flares. It is therefore not surprising to learn that attempts are being made to establish a strontium salt industry near Birmingham.

The *Report* of the Imperial Institute for the year 1936 shows that work in all its departments increased during the year. There were over 700,000 visitors to the galleries, including some 2,300 school parties. The attendance in the cinema hall increased by 20 per cent to 120,000, there was a 17 per cent. increase in the number of

technical enquiries received by the Mineral Resources Department and the Intelligence Department dealt with some 1,200 enquiries from all parts of the Empire. One investigation which may lead to results of great importance dealt with samples of oil-palm fruits from five-year-old trees of the West African oil-palm (*Elaeis guineensis*) grown at Kibarani, 45 miles south of Mombasa in Kenya. The quality of these fruits was quite satisfactory and the Institute was able to report that, grown on a commercial scale, they should enable the colony to share in the lucrative and increasing international trade in vegetable oils. A full report of this investigation is given in Vol. XXXV, No. 1, of the *Bulletin*.

The *Report of the Water Pollution Research Board* for the year ending June 30, 1936, stated that a notable advance has been made in the investigation of methods for the purification of waste waters from dairies and milk products factories. The industry is co-operating in the work through the Milk Marketing Boards and contributed £3,300 towards the cost in the year under review. Purification is effected by the activated sludge process or by biological oxidation in percolating filters.

Investigation of materials for softening water by the base-exchange process has shown that material prepared from British fullers earth is superior to the imported treated clays generally employed and several firms are considering the commercial possibilities of using the home product. Earlier work under the Board had led to the discovery that synthetic resins prepared from certain phenolic substances and tannins possess marked base-exchange properties and can soften comparatively large quantities of hard water. Unlike synthetic zeolites and treated clays now in commercial use, many of these resins are not detrimentally affected by solutions of acids and alkalis. It had also been discovered that resins possessing acid-exchange properties can be prepared from certain aromatic bases. By treating natural waters first with a base-exchange resin and then with an acid-exchange resin the salts in solution can be wholly removed. These important discoveries have opened a new field of investigation and experiments on the properties of many examples of the resins have been continued. The investigation has roused widespread interest and has led to numerous enquiries from all parts of the world. Several commercial firms are now actively interested and some are already manufacturing the resins in small quantities.

The *Annual Report of the Indian Association for the Cultivation of Science* for 1936 contains the yearly balance sheet, rules for the

award of the several short-period professorships, medals, prizes and research scholarships at its disposal and the usual account of the activities of the Association during the year. Research work under the direction of the Mahendralal Sircar professor has been progressing successfully. Seven research scholars were appointed and 16 papers published. Fifty-four papers appeared in the several parts of the Indian Journal of Physics published during the year, 2 from workers in America, 29 from authors working in Calcutta and the rest from different parts of India. It would appear, however, that the publication of the *Journal* is involving the Association in a small loss. The Report, as a whole, gives the impression that the Association is passing successfully through a somewhat difficult period of reorganisation.

The *Bell Laboratories Record* for March, 1937, contains a brief account of a method for producing thin plates of single crystals of water soluble substances. These thin crystals are grown between parallel glass plates in a solution super-saturated by cooling after inoculation with a seed crystal placed between the plates. The *Journal of Research* of the National Bureau of Standards for December, 1936, contains a paper dealing with the stability of the cellulose acetate and cellulose nitrate films used in cinematography. It is concluded that the cellulose acetate type of safety film is very stable and a promising material for library use. The January number of the *Journal* contains an account of a re-determination of the atomic weight of aluminium. The value accepted by the Committee on Atomic Weights of the International Union of Chemistry is 26.97. The new value, obtained by Hoffman and Lundell, is 26.974 ± 0.002 , while Aston's work with the mass spectrograph gives 26.9855 ($O = 16$). Converted to the scale $O^{16} = 16$ Hoffmann's value is 26.9794, which gives a packing fraction -7.6 , as against Aston's value -3.4 , the latter falling well on the mass number-packing fraction graph.

The April number of the *Journal* contains an important paper by Osborne, Stimson and Ginnings dealing with their calorimetric determination of the thermodynamic properties of saturated water in both the liquid and gaseous states from 100° to 374° C. and supplementing their previous work over the range 0° to 270° C. The results are expressed in international joules or "International Steam Table Calories" defined as "1/860 international watt hour, which is equivalent to 4.18605 international joules." This calorie would appear to be sensibly equal to the 15° C. calorie (4.186×10^7 ergs). In this unit the latent heat of a gram of steam at 100° C. is given as

539-12 and the enthalpy of a gram of water at the critical point (374-15° C.) as 498. *Miscellaneous Publication M126*, issued by the Bureau of Standards, is a 4-page leaflet on stout paper containing temperature interconversion tables (° C. \longleftrightarrow ° F) and the melting points and atomic weights of the elements of which only two—numbers 85 and 87—remain undiscovered. The leaflet is obtainable from the Superintendent of Documents, Washington, D.C., price 5 cents.

The *Annual Report* of the Smithsonian Institution for 1935 contains a paper by its secretary, C. G. Abbot, dealing with the results of the long-continued observations of the solar constant at the stations in Chile and elsewhere maintained by the Institution. Twelve periodicities in variation of this constant have been detected, all of them aliquot parts of 23 years, which is the period of the sun's magnetic cycle and about twice the sun-spot period. Indications of an existence of the same period in very diverse weather phenomena have been discovered. The great bulk of the volume (pp. 117-572) is occupied, as usual, by a General Appendix consisting of reprints of important papers descriptive of recent advances in scientific knowledge. These are all very readable and should make the *Report* welcome in any library.

The *Tenth Annual Report* of the Council for Scientific and Industrial Research of the Commonwealth of Australia covering the year ending June 30, 1936, describes the progress which has been made in a multitude of problems mainly of interest to the agricultural community. The prickly pear has been conquered and the improvement of the cleared land for agricultural and pastoral purposes is proceeding steadily, while the Prickly Pear Board is diverting part of its staff to the investigation of insect enemies of other plant pests. Losses due to the peach moth (*Cydia molesta*) have increased enormously in the last three years and have become so great as to threaten the existence of the canned peach industry. Vigorous efforts are being made to destroy the larvæ, but an entirely satisfactory method has not yet been found. Sir Charles Martin's investigations on the virus disease myxomatosis in rabbits have been completed. His experiments showed that the fatality is 100 per cent. in wild European rabbits and that no one had, so far, succeeded in producing the disease in other animals. It is, however, considered that further careful enquiry is necessary before the virus is introduced at large in Australia. The effects on all types of animals is to be investigated under strict quarantine conditions in

Australia itself and, if no ill results follow, a field test will be made, probably on an island, to determine the efficacy of the virus in exterminating rabbits under natural conditions. Progress in the cultivation of the tobacco plant has been held up by downy mildew. It has now been found possible to control this disease by introducing benzol vapour into covered seed beds and it is hoped that it may now be possible to establish the tobacco industry in localities with suitable soil and climate.

The *Report of the National Physical Laboratory for 1936* is printed in the same form as the annual report of the Department of Scientific and Industrial Research, the change of style bringing with it a considerable reduction of cost, which is now only 2s. 6d. net (H.M. Stationery Office, Kingsway, W.C.2). The following extract from the report of the Executive Committee suggests another change in the practice of the Laboratory: ". . . the Committee will be prepared, in appropriate cases, to send members of the staff to manufacturers' work to survey the problem and, where appropriate, to carry out the investigation under the conditions obtaining in the industry." The work of the laboratory continues to increase. The Physics Department reports that some 500,000 clinical thermometers and 7,000 other thermometers were tested and that a British Standard Specification for clinical thermometers has been issued. The Photometry division carried out a secret test to determine the value of the daylight illumination at which a typist switches on her lamp. It was found that, on an average, the light was switched on when the illumination on the work fell to 5 ft.-candles, the spread being from 3 to 8 ft.-candles. The Metrology Department has shown that the discrepancy between the length of the metre as determined at the Laboratory and at the Reichsanstalt is not due to errors in the optical work. A new determination of g has been made and it is hoped to obtain an accuracy of 1 in 10^6 . The Metallurgy Department has patented several new magnesium alloys; those intended for use at temperatures below 150°C . contain aluminium, silver, manganese and calcium, and others intended for use up to 300°C . contain cerium, cobalt and manganese.

ESSAY REVIEW

THE CHEMICAL NATURE OF COAL. By J. W. COBB, C.B.E., B.Sc., F.I.C., Livesey Professor of Coal Gas and Fuel Industries in the University of Leeds. Being a Review of **Coal : Its Constitution and Uses**, by WILLIAM A. BONE, D.Sc., Ph.D., F.R.S., and GODFREY W. HIMUS, Ph.D., M.I.Chem.E., D.I.C. [Pp. xvi + 631, with 22 plates and 114 figures.] (London, New York, Toronto : Longmans, Green & Co., 1936. 25s. net.)

THE appearance of a new book on coal by Professor Bone (this time in collaboration with Dr. Himus) invites at once comparison with his well-known work entitled *Coal and its Scientific Uses*, which was issued in 1918 by the same publishers, as one of the monographs on industrial chemistry edited by the late Sir Edward Thorpe. Pride of place is, however, given in the title *Coal : Its Constitution and Uses* to a feature which is prominent in the new work, and helps to give a special character to it, consisting as it does of a readable and lucid exposition at considerable length of the recent valuable research work of Professor Bone and his collaborators on the chemical nature of coal and allied fuels. This work has aroused lively interest as its results have been brought forward in lectures and scientific journals, but no account of it until now has appeared in collected form. There are other features which place the book in a class of its own, apart from the conventional text-book on a technological subject, and make it one which can be read with advantage by all who desire to be better informed, not only on such things as the occurrence and composition of coals found in this and other countries, and the processes through which coal may be put in use or in preparation for use, but also on economic considerations which are of so much importance in this connection, and must have their influence in determining the right lines of technical development. In this and other respects, the reviewer is reminded of the new approach to a similar subject which was made when, in 1884, Lowthian Bell published his book on the manufacture of iron and steel, "with some notes on the economic conditions of their production." If Professor Bone has been attracted and influenced by the method of treatment

adopted in that work, it is an influence which others have shared, to their advantage, and to that of the subjects with which they have been called upon to deal, primarily by its substitution of an ordered and quantitative analysis of technical problems for the facile descriptiveness which is so often served up in its place.

It is by no accident that sixty pages of Professor Bone's new book are given up to an interesting review entitled *Fuel Economy in the Manufacture of Iron and Steel*, in which Lowthian Bell's researches and views as to limits of fuel economy are clearly explained, and are followed by an account of more recent work bearing on this subject, in which Professor Bone has played a part.

This brings me to an attempt to characterise the book and its method of treatment. It is unnecessary perhaps to recall that in a long career devoted to the science and technology of fuel, Professor Bone has covered as an investigator a considerable range of subjects and has published the results of much highly esteemed original work. This is undoubtedly a great advantage in dealing with a subject so wide as that covered by the book under review, in making it possible to convey the results of a large amount of first-hand knowledge relevant to many issues, and particularly knowledge of many branches acquired by systematic scientific research. It does, however, arouse almost of necessity a disposition to give those branches of work distinctly preferential notice, and, as a consequence, it is not surprising to find in this book some unevenness of treatment. The knowledge of recent work in particular, so much in evidence in those branches of the subject in which Professor Bone and his collaborators have worked and interested themselves, seems lacking at times when other branches come under review. There is all the difference between thorough original treatment and mere mechanical compilation, according to the subject-matter treated. This does not detract at all from the interest of the book as one to read, and indeed adds to its value in the sense that a large proportion of it is presented in an exceptionally interesting and informing way, but its limitation from this point of view has to be noted, not so much for the discerning and well-informed reader, as for the ordinary student, expecting and assuming that more uniform level in treatment of different parts of his subject usually accorded in text-books with a comprehensive title.

The range of this work may now be briefly indicated. Commencing with the economic aspects, to which reference has already been made, there follows a specially valuable and thoughtful chapter entitled "*Britain's Coal Problems*." Such themes as the displace-

ment of coal by oil, the production of oil from coal, the use of low-ash pulverised coal in place of oil, the preparation of low-ash coal, and the use of low-ash pulverised coal in Diesel engines, are in turn the subject of pregnant remarks, and this is followed by a brief account of how the very necessary training of fuel technologists in our Universities has been undertaken in turn by special departments established at Leeds in 1906, London in 1912 and Sheffield in 1920, in addition to courses and research work in connection with some aspect or other of the subject established at other colleges and Universities. It is stressed that although some industries have given generous support, it can scarcely yet be said that, generally speaking, the financial provision for the research work of such departments is commensurate with its importance to the coal industry and the nation. The work of the Fuel Research Board, particularly in carrying out the physical and chemical survey of British coal seams, is also noted, with a suggestion that the outlook of the Board should be broadened, and that it should use the funds at its disposal for the promotion of fuel research throughout the country.

Then comes an excellent account of the origin, formation and classification of coals, including brown coals, lignites, sub-bituminous and anthracitic coals, and a chapter on the coalfields of this and other countries. Next follows a chapter of special value on the chemical constitution of coal, as investigated by the use of solvents and oxidising agents, particularly permanganate. It is there shown how the more recent experiments carried out by Professor Bone and his collaborators have established firmly what had previously been little more than a suspicion, the essentially benzenoid character of the main coal substance, and have proved its progressive development throughout the lignin, peat, coal, anthracite series. To the reviewer, the most valuable part of this particular research work has seemed to be the construction of carbon balance-sheets showing the results of permanganate oxidation, demonstrating not only the occurrence of aromatic products, but their occurrence in such quantities as made it certain that the main substance of the coal and not some minor constituents must have been their source.

A chapter on the preparation of coal for the market is followed by one on combustion and heat transmission in boilers, with some useful information on boiler design and its equipment. The carbonisation industries receive an adequate but conventional treatment, and there is a good account of producer gas. The chapter on water-gas is brief and seems inadequate, in view of the importance which that and analogous means of gasification seem likely

to assume in future. The excellent chapter on fuel economy in iron and steel works, to which reference has been made, is followed by one on power production from coal in central stations, the progress in this direction being clearly indicated. Domestic heating by coal, coke and gas fires is made the subject of a chapter, followed by one on the hydrogenation of coal, mainly taken up by a description of the Billingham plant, for which acknowledgments are made to Mr. Kenneth Gordon. The scientific side of this subject is not unduly stressed, but its beginnings are traced a very long way back to an observation made in 1908 by Bone and Coward that large yields of methane could be obtained by maintaining a mixture of ethane of ethylene with hydrogen at atmospheric pressure for an hour at 800° C.

Examples are given of the application of surface-combustion, and in a final chapter Dr. R. J. Sarjant analyses very effectively and on scientific principles the factors influencing fuel economy and the transmission of heat in industrial furnaces.

There is no doubt as to the value and high quality of this book. The tables and figures are specially well chosen as illustrating the text, but in Figure 24, page 156, the attached description, "Distillation of Silkstone Coal *in Vacuo* at 950° C.," seems to convey the wrong idea. The figure illustrates results obtained by Burgess and Wheeler, by the process of rapid heating at 950°, and should not be confused with the slow distillations *in vacuo* which they conducted at lower temperatures. The same figure appears in *Coal and its Scientific Uses*.

REVIEWS

MATHEMATICS

Mathematics for the Million: A Popular Self Educator. By LANCELOT HOGGEN. Illustrations by J. F. HORRABIN. [Pp. 647, with frontispiece and 197 figures.] (London: George Allen & Unwin, Ltd., 1936. 12s. 6d. net.)

THIS lively and provocative book is a brilliant *tour de force*. It is intended to remove the inferiority complex of "some of the million or so intelligent people who have been frightened by mathematics while at school." Its theme is that the history of mathematics is the mirror of civilisation, reflecting its progress stage by stage. Its argument is that all fruitful (i.e. socially useful) intellectual activity is limited by the general level of social culture of the time, and beyond that point speculation, even by the cleverest, is bound to end in barren isolation from common life and to become "the plaything of a leisured class." The mathematician and the ordinary man both need each other, and it is therefore of prime importance that we should all know something about mathematics. Its scheme in the author's own words is this: "The customary way of writing a book about mathematics is to show how each step follows logically from the one before without telling you what use there will be in taking it. This book is written to show you how each step follows historically from the step before, and what use it will be to you or someone else if it is taken."

We begin with the earliest attempts at counting and measurement (the beginnings of a "size language"), developed by the Egyptian builders into a system of geometry. The Greeks took this over, and as they became prosperous it degenerated in their hands into a plaything of abstractions. The scene shifts to Alexandria, the world's shipping centre, where trigonometry measured the size of the earth and the distances of sun and moon. Such measurements involved numbers too great for existing counting systems to manipulate, and the next advance came with "the dawn of nothing," the Hindu zero and numerals, developed by the Arabs, spread by the sweep of Moslem civilisation, and brought along the trade routes into Western Europe. With this powerful instrument the treasure box was opened. The great navigations involved more accurate tables of star measurements, and logarithms were invented to calculate them. Mathematicians were now thinking in terms of maps, longitude and latitude. With the invention of mechanical clocks the world was ready for Descartes' new geometry which took count of time and opened the way for the calculus, the measurement of change and the foundation of the modern studies of probability and statistics.

This bald summary necessarily omits many of the important topics dealt

with in a long book, packed with interesting and out-of-the-way information and written with unflagging energy and unity of purpose. Anyone who has worked through it and tackled the exercises at the end of each chapter will have made acquaintance with the elements of arithmetic, geometry, plane and spherical trigonometry, algebra, logarithms, graphs, calculus and statistics. If this means that the average reader of *SCIENCE PROGRESS* will not have learned any new mathematics, he will certainly have acquired a new view of the interdependence of its parts.

It would be graceless to say much in criticism of such a brilliant pioneering effort, but a few impressions out of many may be recorded. The attempt to be popular and to avoid "jargon" involves some long-winded discussion and even leads to some new technical terms, such as "back numbers" (for negative numbers), whose associations may be confusing. So too the analogy worked out at great length between mathematical and ordinary grammar (in which, for example, the sign " $=$ " is translated by the infinitive verb "to get") seems hardly likely to be more helpful than the similar spoon-feeding expedients of phonetics or sol-fa. But the main defect of the book is the all-pervading note of contemptuous intolerance for all work not directly concerned with achieving the social millennium as the author sees it. His insistence that no enquiry is of value unless undertaken with a social purpose enables him to heap ridicule upon those whom he dislikes in every age, including all priests and most professors. It is very amusing, but it is not mathematics—or rather perhaps it is just left-wing mathematics. Nor is it always consistent: Plato is roundly condemned for treating geometry as a plaything and running it into a dead end, but the Pythagoreans, who also had independent incomes and played equally happily with triangular numbers, escape with a mild caution, because these numbers afterwards proved to have a bearing on the binomial theorem and statistics. Nor is it true: history is too full of examples to the contrary, from the analysis of pendulum motion to Riemann's geometry and matrix algebra, to persuade us that the suppression of pure human curiosity would not put an end to practical human progress. Too much need not be made of the author's gibes, for he himself asks us not to take them too seriously, and the book remains one which everyone, mathematician or not, should read with profit, preferably with pencil and squared paper before him and a salt-cellar at his left elbow.

A word of praise must be added for Mr. Horrabin's illustrations, which are uniformly clear and valuable. There is a slight slip in Fig. 101 (p. 276), where what purports to be a parabola would actually, if completed, be an ellipse.

B. W. F.

Heaviside's Operational Calculus : as Applied to Engineering and Physics. By ERNST JULIUS BERG, Sc.D. Second Edition. Electrical Engineering Texts. [Pp. xvi + 258, with 102 figures.] (New York and London : McGraw-Hill Publishing Co., Ltd., 1936. 18s. net.)

THIS book is the second edition of a work already well known to those interested in the more mathematical aspects of electrical engineering. In order to follow the methods described, the reader requires a fair knowledge of differential and integral calculus, though the main object of the book is to show how the operational methods developed by Oliver Heaviside avoid

many of the difficulties inherent in the more formal methods of solving differential equations.

Although the fundamental features of the method are adequately treated, and several chapters are devoted solely to this purpose, a very large portion of the book is taken up with the applications of Heaviside's methods to the solution of specific problems. A long appendix is also devoted to this latter purpose, numerous practical problems being worked out in detail. In view of Heaviside's own contributions to electrical theory, and the fact that most of his mathematical work was applied to this end, it is not surprising that the problems selected by the author are mostly electrical, though one short chapter is devoted to the solution of a problem in heat conduction.

In addition to the direct exposition of operational calculus, some attention is given to algebraical problems arising out of it, notably the solution of equations containing high powers of the variable.

A pleasing feature of the book is that the personality of the originator of the mathematical methods described is not ignored. In addition to a foreword giving a brief account of the life of Oliver Heaviside, there is a long chapter by B. A. Behrend which gives an account of his work with many intimate glimpses of his personality.

The book can be confidently recommended to engineers who desire to acquire a knowledge of Heaviside's valuable contribution to the methods available for attacking the more abstruse problems which arise in electrical theory.

H. M. L.

Introduction to the Theory of Linear Differential Equations.

By E. G. C. POOLE. [Pp. viii + 202, with 5 figures.] (Oxford : at the Clarendon Press ; London : Humphrey Milford, 1936. 17s. 6d. net.)

MR. POOLE has made a valuable addition to the literature of the subject and it is a great pleasure to find, in English, much that has, hitherto, only been available in German and in French. This is not meant to be a book for beginners but "for students who have already taken an elementary course in differential equations." One must say that some knowledge of matrix algebra is also essential for its understanding.

In the first chapter existence theorems are given and the conditions for linearly independent solutions. The next two chapters give an honest account of Heaviside's operator $\frac{1}{p}$, the well-used D , $\delta = xD$ and other linear operators. Chapter IV gives a very clear account of the different types of singularity and is followed by a discussion of solutions in the neighbourhood of regular and apparent singularities.

The end of this chapter seems to divide the book into two parts although the question of singularities leads naturally to a discussion of Riemann's P function. This is a more than usually clear account of this function and Mr. Poole makes a careful study of the identities between its different branches. It is consistent with the scheme of the book that the work of Barnes and others should be excluded, but we are given a valuable account of other integrals used to express Hypergeometric functions. The chapter on conformal representation is not a first course in this art but an account of some special problems allied to the work of the previous chapter.

The last three chapters concern Laplace's Linear Equation leading to the Confluent Hypergeometric Function and thence to Bessel's Equation, Lamé's Equation and Mathieu Functions. In this part of the book the reader is evidently meant to be familiar with the better-known functions; in particular, the σ -function appears first in "the well-known formulæ"

$$[\wp(u) - e_i]^{\frac{1}{2}} = \frac{e^{-\eta_1 u} \sigma(u + \omega_i)}{\sigma(u) \sigma(\omega_i)},$$

There are numerous examples, many of them with references to original papers, and the book is very well printed.

C. M. RIGBY.

Differential and Integral Calculus. Vol. II. By R. COURANT. [Pp. x + 682, with 112 figures.] (London and Glasgow: Blackie & Son, Ltd., 1936. 30s. net.)

This book should be of value to a wide class of mathematicians. The present volume is concerned with some of the more advanced parts of the Calculus, such as applications to functions of two or more variables. The author is a great teacher, and his first object is to make the book readable. His method of dealing with a difficult idea is to present it perhaps as many as three times; first as a plausible idea based on geometrical intuition, then in a formal proof in which, if advisable, certain difficult, though plausible, assumptions are made, and finally in an appendix at the end of the chapter, where the outstanding points are discussed for the benefit of those who are interested. The book is not intended for those mathematicians whose main object is the lightening of hypotheses or strengthening of conclusions, regardless of the extent to which they lengthen or complicate proofs. The author is only concerned with good wholesome sufficient conditions, which turn up in practice, and straightforward necessary conditions. Thus, for instance, there is no mention of rectifiable curves, but only of sectionally smooth curves, i.e. curves given parametrically by functions whose derivatives are continuous in a finite succession of intervals of the parameter. On the other hand the author takes us far enough to give us an interesting introduction to the necessary conditions for an extremal in the Calculus of Variations in any number of dimensions.

It is only possible here to give a brief synopsis of this volume. Ch. I. Preliminary remarks on Analytical Geometry and Vector Analysis. Ch. II. Functions of several variables and their derivatives. Vector methods. Ch. III. Implicit functions. Transformations. Families of curves and surfaces. Envelopes. Maxima and minima. Ch. IV. Multiple integrals. Ch. V. Line and surface integrals. Ch. VI. Differential equations. Fundamental equations of Applied Mathematics and Physics. Ch. VII. Calculus of Variations. Ch. VIII. Functions of a complex variable. There are also copious examples, as well as answers and hints.

It should be mentioned in conclusion that the standard of accuracy is high. The mathematics has been presented with great care. It has been well translated from the original German by Prof. J. E. MoShane, and a number of improvements and additions have been made. The type is well set up and there are very few misprints. The reviewer has confidence in recommending this book to mathematicians and also to mathematical physicists.

L. S. B.

Elements of Probability. By H. LEVY, M.A., D.Sc., F.R.S.E., and L. ROTH, M.A. [Pp. x + 200, with 25 figures.] (Oxford: at the Clarendon Press; London: Humphrey Milford, 1936. 15s. net.)

SOME seek to avoid loss, or to obtain gain. Thus have arisen the practices of insurance and of gambling; and with these practices came the beginning of the theory of probability. After an interesting historical introduction, the authors proceed to discuss the scope of probability. Whilst recognising "mathematical" and "statistical" probability, and "probability as a branch of logic," they consider that "a probability estimate, however it is approached, has to be seen and interpreted as a guide in scientific procedure."

The book can be recommended as giving a good account of the elements of Mathematical Probability. The subject is developed from its foundations, and without the use of much advanced mathematics. Moreover, a number of examples are worked out in the text and others are left as exercises for the reader. The examples are, however, mainly concerned with mathematical probability itself; and little space is devoted to the application of probability to actual statistical or experimental data. A good account is given of "The Theory of Arrangements," but the treatment is not extended to include the beginnings of statistical mechanics. The concluding chapters deal with the empirical theory of distributions, and the use of probability in scientific induction.

W. N. BOND.

ASTRONOMY

The Realm of the Nebulæ. By EDWIN HUBBLE. [Pp. xii + 210, with 15 plates and 16 figures.] (London: Oxford University Press, 1936. 12s. 6d. net.)

THIS authoritative account of the extra-galactic nebulæ by the principal worker in this branch of astronomy is an expansion of a course of Silliman lectures delivered at Yale University in 1935. It constitutes the twenty-fifth volume published on that foundation, and the series in many ways resembles the older and better-known Gifford Lectures of the Scottish Universities.

Only within the last twenty years have the confines of human knowledge been extended to the realm of the nebula; an extension made possible only by the successful construction of the 100-inch Hooker telescope and by the skill of Dr. Hubble in its use. In this book he is therefore describing a new phase of astronomical research, and, approaching it from the point of view of the practical observer, he indicates clearly the steps by which so much positive knowledge has been accumulated, as well as the boundaries beyond which pure speculation still holds sway. Each criterion of nebular distances, necessarily limited in its application, has been used to calibrate another, less precise but of greater range. The Cepheid variables, observable only in the nine systems which compose the "local group," provide the reliable foundation upon which estimates of all nebular distances are built. For more distant systems in which certain giant stars but no Cepheids can be observed, the magnitudes of these stars are utilised on the assumption that they are of the same order of luminosity as those found in members of the local group. This method has provided the distances and dimensions of 125 systems. Still deeper sounding of space proceeds on the assumption that the average intrinsic luminosity of the nebulæ is a criterion of their distance, and this

method, though naturally 'unreliable for individual cases, is useful when considerable numbers are dealt with statistically. Finally, there is the Velocity-Distance Relation, which, if the red-shifts in the nebular spectra really indicate recession, shows an increase of velocity of 105 miles/sec. for each million light years of distance. When the red-shifts have been measured, the distances, therefore, can be readily calculated, and, even if the velocity interpretation of the shifts is abandoned, and they are ascribed to some as yet unknown principle of Nature (to which view the author seems to incline), their usefulness for estimating distances remains unimpaired.

An attempt to form a conception of the universe is complicated by the large differences in time required for light from the various systems to reach the observer. Dr. Hubble leaves his readers with a picture of many millions of nebulae which form an ordered sequence, ranging from globular and ellipsoidal figures to a series of unwinding spirals which suggest increasing speed of rotation. These systems are found singly or in groups, but, when averaged out, their large-scale distribution is approximately uniform in a sphere 500 million light-years in radius.

This may be taken as the contribution of the 100-inch telescope towards the solution of the problem. Few will be so rash as to prophesy what modifications and extensions will be revealed by the 200-inch reflector now under construction.

R. W. W.

SEISMOLOGY

Great Earthquakes. By CHARLES DAVISON, Sc.D., F.G.S. [Pp. xii + 286, with 12 plates and 97 figures.] (London: Thomas Murby & Co., 1936. 17s. 6d. net.)

A FEW years ago Dr. Davison wrote an authoritative account of the great Japanese earthquake of 1923 and he has now followed this up with a companion volume dealing with eighteen of the greatest earthquakes of the last 200 years, from the Lisbon earthquake of 1755 to the New Zealand disaster of 1931. The shocks were chosen not merely on account of their great violence, but chiefly because a large amount of reliable information was available for each case.

Since the development of sensitive seismographs a large amount of seismological investigation has been carried out, from the physical and mathematical standpoints, and there is perhaps a tendency to regard the earthquake mainly as a source of material for research in the propagation of elastic waves. Dr. Davison's book gives us a timely reminder of the other important aspects of seismological investigation—aspects which have more direct bearing on human activity and on surface features of the earth. The author deals with the earthquakes as major events in the history, physiography and geology of the regions in which they occurred. Noteworthy phenomena accompanying the shocks, such as deformations and dislocations of the earth's crust, seiches and seawaves, are described and much information is given concerning the loss of life and property, the intensity and nature of the shocks, and the areas of disturbance.

It is of interest to note that although practically all of these great earthquakes were followed by long series of comparatively small after-shocks, in only one or two cases were they preceded by any shocks which could be regarded as warnings of an approaching calamity.

Dr. Davison has done a very useful piece of work in collecting together a vast amount of information from extremely scattered sources and his book is a notable contribution to the study of earthquakes.

F. J. S.

Earthquakes. By NICHOLAS HUNTER HECK. [Pp. xii + 222, with 88 figures.] (Princeton : Princeton University Press ; London : Humphrey Milford, 1936. 16s. net.)

THE author of this book, as Chief of the Division of Terrestrial Magnetism and Seismology in the United States Coast and Geodetic Survey, has taken a large part in the development of a highly efficient seismological organisation, the work of which is proving to be of great use, not only in the United States, but in many other parts of the world. With the development of modern instruments, rapid advances have taken place in the study of earthquakes and it is to satisfy a demand for a popular account of modern ideas on the subject that this book has been written.

The book is intended for the general reader rather than for the specialist and the treatment is entirely non-mathematical. The author has aimed at giving a broad picture of seismology in all its aspects and he has succeeded in producing an extremely comprehensive account of the subject. In the earlier part of the book the causes and effects of earthquakes are discussed ; then follows an account of the methods, instrumental and non-instrumental, by which earthquakes are investigated. It will interest many readers to know how seismic waves are turned to good account by using them to obtain information about the earth's interior ; this method of exploring the depths of the earth is very similar to the application of sound-waves and radio-waves in exploring the upper layers of the atmosphere.

A fairly large part of the book is devoted to a description of the regional investigation of earthquakes which is now being carried out in America ; the results of this very determined attack on the problem promise to be extremely useful. Probably the most important chapter, from the practical point of view, is that dealing with safe construction in earthquake regions, for although no amount of investigation can prevent earthquakes from occurring, it can be of much use in showing how danger to life and property can be minimised by suitably constructed buildings.

The book is well illustrated and it can be recommended to the layman as a reliable source of up-to-date information on seismology.

F. J. S.

PHYSICS

The Theory of the Properties of Metals and Alloys. By N. F. MOTT, M.A., F.R.S., and H. JONES, Ph.D. The International Series of Monographs on Physics. [Pp. xiv + 326, with 108 figures.] (Oxford : at the Clarendon Press ; London : Humphrey Milford, 1936. 25s. net.)

THOUGH Quantum-mechanics was founded only about ten years ago its application already extends over wide regions of Physical Science. One of the fields where it has proved very fertile indeed is that opened up by Sommerfeld, in 1928, when he considered the motion of the "free" electrons in a metal on the basis of the new ideas. Sommerfeld's investigations were soon extended by other workers, and there has since been little abatement in the rate of progress. The result is that a large number of the general

properties of metals and alloys, and also many of their individual characteristics, can now be explained in terms of the fundamental principles of Quantum-mechanics. The book in front of us is an account of these important developments and achievements of physical theory, by authors who are themselves responsible for many of the recent advances.

The book covers all the effects which have so far been treated by the new theory. Contributions which appeared too late to be mentioned in the text are referred to in notes at the end of the chapters concerned. The requirements of the research worker are thus fully met. The physicist who has not specialised in this field need however not seek elsewhere for an introduction to the subject. He will be able to acquire from this book a general understanding of it provided he has a previous acquaintance with the wave-equation of Schrödinger and with the Fermi-Dirac statistics, such as can be obtained from any elementary text-book on Quantum-mechanics. This is so because the authors have everywhere endeavoured to explain, rather than to describe, the theory. Where any advanced theory is required it is adequately discussed beforehand. The general reader will particularly be helped by the full treatment of the one-dimensional problem which in the earlier chapters generally precedes the consideration of the actual problem presented by a three-dimensional lattice.

The first chapter is devoted to problems, such as the specific heat and equation of state, which can be treated without specific reference to the free electrons. The general theory of the free electrons is given in the two chapters which follow, one of which deals with the nature of the stationary states of the electrons, the other with the process of conduction under the action of an external electric field (including the absorption and dispersion of radiation). The detailed theory of the stationary state, taking into account the differences between different metals and alloys, is developed in the fourth, fifth and sixth chapters, which deal respectively with cohesion, crystal structure and the heat capacity and magnetic properties associated with the free electrons. The last chapter on electrical resistance is a similar development of the general theory of conduction given earlier in the book.

In the case of all the phenomena dealt with the relation of theory and experiment is fully discussed. This will make the book as invaluable to the experimentalist in this field as it will be to the theoretical investigator.

E. J. W.

The Physics of Solids and Fluids. By P. P. EWALD, TH. PÖSCHL and L. PRANDTL. Authorised translation by J. DOUGALL, M.A., D.Sc., F.R.S.E., and W. M. DEANS, M.A., B.Sc. Second edition. (Pp. xiv + 396, with 325 figures.) (London and Glasgow : Blackie & Son, Ltd., 1936. 17s. 6d. net.)

IN 1930, when the first edition of this book was published, the collection in one volume of all the principal facts with regard to the physics of both solids and fluids was so acceptable a novelty that criticism of the manner in which the facts were presented would have been invidious. The publication of the second edition has now afforded the authors an opportunity to recast their material, and criticism of the presentation seems no longer out of place.

Unfortunately, the authors have made little use of their opportunity, for the alterations from the first edition represent little more than annotations

to the original text. The book contains several passages of outstanding value: Pöschl achieves a masterly summary of the mathematical basis of the theory of elasticity: Ewald contributes an excellent review of Born's theory of the crystal lattice: whilst Prandtl's section, which constitutes more than half the whole work, includes a very valuable account of the flow of compressible fluids at velocities exceeding that of sound. This latter section is the only major addition to the new edition.

On the other hand, the high standard set by the best passages serves to emphasise the lamentably lower standard of other sections, and it is the lower standard which predominates. Pöschl's remarks on recrystallisation, Ewald's summary dismissal of elastic hysteresis in single crystals and Prandtl's discussion of Borda's mouthpiece illustrate the authors' worst styles; but many of the offending passages seem to have suffered in translation and the authors have clearly been hampered by exigencies of space. For this reason, it is the more surprising that 14 pages should have been wasted on an entirely elementary discussion of friction. Incidentally, the inclusion of a reference to simple machines at the end of this chapter may perhaps be regarded as a mild joke.

The chief disappointment of the second edition lies, however, in the complete lack of co-ordination not only between the contributions of the individual authors but also between different passages in the same section. Prandtl, for instance, introduces Bernoulli's theorem some pages before he mentions the momentum equations and in later sections permits the reader to gain the impression that the two theorems are virtually independent. Ewald makes one reference to Pöschl's section, but only one, and practically contradicts Pöschl as to the value of "phenomenological" (a word the translators might have spared us) research. Ewald and Pöschl give two independent explanations of the conception of stress, neither explanation being at all adequate to the purpose of the book.

As a whole the work may be likened to a symphony played by musicians of very varying abilities, without the help of a conductor.

H. L. Cox.

Principles of Electric and Magnetic Measurements. Part I: Electricity, by P. VIGOUREUX. **Part II:** Magnetism, by C. E. WEBB. *The Student's Physics*, Vol. VII. [Pp. xii + 392, with 197 figures, including 2 plates.] (London and Glasgow: Blackie & Son, Ltd., 1936. 20s. net.)

ALTHOUGH the book under review is undoubtedly of considerable interest to physicists in industrial, research or teaching institutions, it may as well be emphasised at the outset that from one or two pedagogic points of view it is disappointing. For example, the authors themselves state that in order to facilitate reading, names are seldom quoted in the text and no references are given to the text-books or papers consulted. This to the reviewer's mind is an unfortunate attitude at a time when university and other institutional libraries are doing their utmost to enable students and others to consult original papers and sources of information. Whether or no certain learned societies and workers will be pleased with the authors' further statement that the number of text-books or papers consulted is too great for detailed acknowledgments to be made is not the reviewer's concern.

Again, one or two sections of the book in which teachers are particularly

interested are not well done, and, indeed, could really have been omitted. Thus, the chapter on electric charges in electric and magnetic fields with its inadequate accounts of the determination of e/m and of X-rays might easily have been curtailed, although the section on the cathode ray oscillograph in the same chapter is quite helpful.

The main interest of the work in the reviewer's opinion lies in the fact that the authors are very much *au fait* with modern developments in electrical measurements; in particular, they have a grasp of alternating current bridge methods and of high frequency technique which enables them to write with clearness and conciseness on many important matters which are not always fully discussed in the teaching laboratories. In many instances they give practical details which are often ignored elsewhere; e.g. they mention that neutral and acid Weston standard cells are used, although the average student is unaware that there is any difference in the types supplied.

A few points call for comment. It is a little unusual to see the permeability of a material stated in terms of henrys per metre and a dielectric constant in terms of farads per metre. One would like to see some elaboration or proof of the formula given as applicable in the case of the dynamometer developed by Moullin for the measurement of alternating currents of high frequency. The discussion of the Wagner earthing device in capacity bridge measurements and other bridge arrangements is very good. The descriptions of hot-wire instruments, including the hot-wire oscillograph, are very interesting. A complete account of the determination of the electrochemical equivalent of silver is given, but, in contrast to this, the description of the determination of the ohm in absolute measure might well be amplified. It merely remains to state that for some time to come the book will be important because of the new instruments, etc., of which it gives account—but references are certainly indispensable.

L. F. B.

Electronics and Electron Tubes. By E. D. McARTHUR. [Pp. vii + 173, with 89 figures.] (New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd., 1936. 12s. 6d. net.)

This book is based upon a series of articles with the same title published in *The General Electric Review* (of America) a few years ago, and is intended to describe "the fundamental principles which govern the action of all electron tubes," without the use of mathematics. If something more than general electron theory is intended and if the term "electron tube" is used in its widest sense, this is a formidable task. We find, however, that the author has rather arbitrarily restricted his scope; for example, he does not mention any application of secondary electron emission, such as the electron multiplier—indeed he states on p. 38 that "secondary emission phenomena are not used commercially to any great extent." Surely most people would prefer to have described the Zworykin Iconoscope and Electron Telescope rather than the selenium cell or vacuum switch. X-ray tubes, electron microscopes and the like are also omitted.

The first 18 pages are devoted to atomic theory preparatory to Chapter 3, which deals briefly with methods of electron emission, Schottky effect, etc. The account of space charge effects is particularly good. Chapter 4, entitled "Two-Electrode Tubes," includes photoelectric and selenium cells and the high-vacuum diode. In connection with the next two chapters (on triodes

and other thermionic vacuum tubes) it is perhaps a pity that the characteristic curves refer to high-voltage tubes; the ordinary man is more used to anode voltages of hundreds than thousands. Also, the descriptions of amplifiers would be difficult to follow with only the information given in previous chapters. Chapters 7 and 8, on gas-filled tubes, occupy a comparatively large space, but this is justified in view of the increasing importance of these tubes, and the author is obviously at home here. The book ends with very brief descriptions of a few special tubes, such as the cathode ray oscillograph, and an account of the construction of electron tubes in general.

At the end of each chapter there is a useful bibliography. The book is well printed and bound, while only one misprint has been noticed (in the equation on p. 5). Some of the photographs of complete tubes are too small to be of much use and may well be replaced by a few good diagrams. The book will be of service to those desiring a general introduction to electron tube theory.

F. A. V.

Wireless Engineering. By L. S. PALMER, D.Sc., Ph.D., F.Inst.P. [Pp. xii + 544, with 353 figures.] (London, New York, Toronto: Longmans, Green & Co., 1936. 21s. net.)

SINCE its publication in 1927, Prof. Palmer's *Wireless Principles and Practice* has been one of the best known of the standard text-books on radio engineering. The book now under review is a revised edition of the earlier one and, although most of the original subject-matter has been retained, the additions are so extensive that the change in title is fully justified.

As one would expect, the author is at his best when dealing with the propagation of radio signals, and the recent work on the ionosphere and on beam aerial systems is adequately described.

The chapters dealing with the generation, detection and amplification of high-frequency currents are less satisfactory and, to the present writer, appear somewhat unbalanced. Thus 30 pages are devoted to spark, arc and alternator methods of generation, while Barkhausen-Kurtz oscillators and the various forms of magnetron oscillator receive only 2 pages in all. Again, several obsolete detectors are described at some length, while the superheterodyne method of reception is dismissed in one page and valves with more than four electrodes do not appear to be mentioned.

These criticisms, however, apply only to a comparatively small portion of the book, which, on the whole, admirably fulfils its purpose and provides a sound general background for more specialised works.

C. W. O.

A Textbook of Physics, for Students of Science and Engineering.

By CHARLES A. CULVER. [Pp. x + 816, with 525 figures.] (New York and London: Macmillan & Co., Ltd., 1936. 17s. net.)

THE book under review is intended to form the basis of a comprehensive year's course in physics for students of science and engineering. A working knowledge of trigonometry and a very slight acquaintance with calculus are assumed. At the end of most of the chapters a few questions are given for the reader to solve. The author believes that in a number of modern physics text-books rather too much space has been devoted to the "new physics." He aims primarily at letting the student get a clear grasp of the more classical

parts of physics ; but he introduces the newer concepts wherever it appears appropriate to do so.

The author has had considerable teaching experience, and has written a book which is, on the whole, very satisfactory. All the main branches of the subject are treated, though the section on Sound is rather brief. The standard of difficulty is between that of an English University first-year course and the standard required for a pass degree. For instance, the theories of the work scale of temperature, of Poiseuille's equation and of the bending of a beam are omitted, though the equation for the torsion of a wire is given in an appendix. Thick lenses and the defects of a lens are discussed slightly ; and there are sections on diffraction, alternating currents, electronics, X-rays, electro-magnetic waves and radioactivity. An illustration shows Moseley's celebrated photographs of X-ray spectra ; and brief references are made to the quantum theory.

Though the book, taken as a whole, is satisfactory, yet a number of criticisms might be made. Some mistakes occur, such as an incorrect diagram of Hare's apparatus. In dealing with mass and force, both "absolute" and "gravitational" units are discussed, but the treatment of the latter is by no means perfect. In the treatment of mirrors and lenses, a convention of signs is used which is not often met with in English school or university text-books. When a real image (of a real object) is formed by concave mirror or convex lens, all the distances concerned are taken to be positive. This convention was one of the two (namely Group II, Case 1) recommended in the *Report on the Teaching of Geometrical Optics*, published by the Physical Society in 1934. It has the advantage of making the focal lengths of converging systems positive. The Author, however, leaves the student to insert or interpret negative signs by comparing his particular problem with one of the two standard instances mentioned above.

W. N. BOND.

Elementary Physics : for Medical, First Year University Science Students and general use in Schools. By G. STEAD, M.A.
Fifth edition. [Pp. xv + 560, with 430 figures.] (London : J. & A. Churchill, Ltd., 1936. 12s. 6d. net.)

MANY years ago a student told me that he wished to sit for the Pre-medical examination of a certain University. I asked him if he knew anything about the syllabus in Physics and his reply was "No, except that it covers the whole of Heat." Subsequent enquiry showed that the student's impression was that the whole of Heat was limited to the contents of a well-known elementary text-book. This *Elementary Physics* was first published in 1924, and has been reprinted three times, a fact which shows that the book fulfilled a useful purpose. Personally, I did not consider that those earlier editions covered sufficient groundwork for medical students in a subject so wide and of such importance in its practical applications and its cultural significance. In this fifth edition the author has carefully revised the older text and has added some one hundred pages of new material. Mr. Stead is to be congratulated warmly on the clarity of his exposition and on the happy choice of subject-matter necessary to make his text-book an adequate guide for a student working for an examination on a syllabus covering "the whole subject treated in an elementary manner and with special reference to its applications in the subsequent work of the student." The inclusion of a short account

of the more recent developments in Physics is very welcome because of their great general interest. I venture to make one or two suggestions for Mr. Stead's consideration. The balance is described as a rigid beam supported on a knife-edge; there should be some indication, in the text or by means of a diagram, that these knife-edges are fixed in the beam itself. In the discussion of the laws of viscous flow the example of the delivery of water through 10-inch and 12-inch mains is unfortunate because, in general, such flows will be turbulent. It is good to find a reference to the report of the International Committee, 1934, in the definition of the gramme-calorie, but, having used this unit in defining thermal capacity, why not continue and give specific heat (or thermal capacitance) in appropriate units? Some short account of continuous-flow electrical calorimetry should find a place in all books of this standard.

J. H. BRINKWORTH.

The Renaissance of Physics. By KARL K. DARROW, Ph.D. [Pp. x + 306, with frontispiece and 44 figures, including 16 plates.] (New York and London: Macmillan & Co., Ltd., 1936. 12s. 6d. net.)

THE book owes its existence largely to Dr. Darrow having been invited to give a course of lectures before the Lowell Institute in Boston; but he states that the scope of the book extends considerably beyond that of the lectures.

The word "Renaissance" he uses to describe the rapid development of physics that has taken place since the closing years of the nineteenth century. It is pleasing to find the present state of physics aptly likened to the state of arts and humane letters four hundred years ago; pleasant to have it pointed out that many of the heroes of physics are alive now, and that physics is not living entirely on its past. We ought not, however, to forget the earlier developments in physics; a considerable amount of important work was carried out between the times of Faraday and Röntgen.

In the main, the book deals with discoveries in atomic and sub-atomic physics. It is assumed that the reader may be almost, if not quite, ignorant of physics. Elementary parts of physics are introduced and explained briefly wherever they are necessary to the understanding of the subject. There are various consequences of this method of treatment. On the one hand, it enables the author to deal with old topics in a novel and illuminating way. On the other hand, many points have to be treated cursorily; and various references are made to matters which are to be explained in later portions of the book.

The half-tone illustrations are good, and together with the line diagrams help in explaining a complex subject. It is necessary, however, to have a very large set of good illustrations if an experimental subject is to be explained clearly to one previously unacquainted with it. The chief defects of the book are due to such an ambitious programme being attempted, in one volume, without the possibility of accompanying the description with actual experimental demonstrations.

W. N. BOND.

You and the Universe. By PAUL KARLSON. Translated by BERNARD MIALL. [Pp. 325, with 165 sketches and 8 plates.] (London: George Allen & Unwin, Ltd., 1936. 12s. 6d. net.)

THIS book is written by a young physicist of twenty-five, and has the ambitious sub-title of *Modern Physics for Everybody*. His first book was on gliding,

and the success of this induced his publishers to press him to write a volume which had the original title of *Du und Die Natur*. In spite of this, it must be said at once that the book is excellent, and that the author has succeeded with the help of his illustrator in producing a sprightly, amusing, and informative account of the most fascinating portions of modern physics. Relativity, quantum theory, neutrons, positrons, probability and indeterminacy—nothing is too abstruse for vivacious and lucid illustration. Only when he comes to one of the oldest problems in the world does he fail—Achilles and the Tortoise: he has not realised how many “problems” are a matter of definition. This is a unique book and will interest and entertain anyone who is capable of reading.

G. B. BROWN.

Handbook of Engineering Fundamentals. Edited by OVID W. ESHBACH. Wiley Engineering Handbook Series, Vol. I. [Pp. xii + 1082, with illustrations.] (New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd., 1936. 25s. net.)

THE publishers of this book produce a series of handbooks on mechanical and electrical engineering and, in order to avoid the overlapping which must otherwise exist in such a series, they have collected in the present volume the material which is common to all engineering. The bulkiness of the specialised volumes is thus decreased with obvious advantages in convenience to their users.

Whether it is quite correct to describe this common material as “the fundamental laws and theories of science which are basic to engineering practice,” as the editor does in his preface, is open to argument and will depend upon the reader's definition of the word fundamental. To many, the present volume will appear to depart from the strict interpretation of the word, perhaps most notably by the inclusion of a section on Contracts. However useful this may be, it can hardly be described as fundamental science.

This criticism, however, is somewhat pedantic and does not alter the fact that the editor and his forty collaborators have produced a volume which gives in a most useful and handy form a mass of information which is constantly required by the engineer, and in doing so they have done valuable service to the profession.

The ground covered is so wide that it is quite impossible in a single review to do more than give a general idea of the scope of the book, and this is best done by quoting the titles of the fourteen sections into which it is divided. These are Mathematical and Physical Tables; Mathematics; Physical Units and Standards; Theoretical Mechanics; Mechanics of Materials; Mechanics of Fluids; Engineering Thermodynamics; Electricity and Magnetism; Radiation and Light; Acoustics and Meteorology; Chemistry; Metallic Materials; Non-metallic Materials; and Contracts.

The Index, which in a book of this type is all-important, is excellent both in its arrangement and completeness. The book is well printed on good paper, is of a handy size and should prove a very useful addition to the library of any engineer.

A. J. S. P.

CHEMISTRY

Gmelin's Handbuch der anorganischen Chemie. 8. Auflage. Herausgegeben von der Deutschen Chemischen Gesellschaft. System-Nummer 4: *Stickstoff*, Lieferung 1-4; System-Nummer 55: *Uran und Isotope*. (Berlin: Verlag Chemie, G.m.b.H., 1934/36.) *Stickstoff* [pp. xviii + 1060, with 112 figures] RM. 124.90. *Uran und Isotope* [pp. xxviii + 279, with 4 figures] RM. 34.50.

THE object of this article is to review five of the recently edited issues of *Gmelin's Handbuch*. As it is the first time that attention is paid in these columns to the appearance of the eighth edition of *Gmelin*, it might be appropriate to begin with a brief description of its general character, especially of the points in which it differs from other comprehensive treatises on inorganic chemistry.

Probably every chemist would agree that there are many books on organic chemistry, but only one *Beilstein*. Equally we may claim that, in spite of a great number of treatises on inorganic chemistry the standard of *Gmelin* is unique. There is more than a superficial analogy between these two outstanding works: both were started as the private enterprise of a single man, but are now edited under the supervision of the German Chemical Society by a large staff of chemists who devote their full time to the work; both aim at such completeness of material, accuracy of references and expert criticism as cannot be attained by any work on a smaller basis.

Comparison with *Beilstein* will make it obvious too that there is hardly any competition between *Gmelin's Handbuch* and other reference books. We possess comprehensive modern works on inorganic chemistry in English and French. They have, compared with *Gmelin*, the advantage of comprising all the chemical elements (at least two or three of them do), and of being obtainable at a lower price. The new edition of *Gmelin* contains so far the following elements: the rare gases, hydrogen, nitrogen, fluorine, chlorine, bromine, iodine, boron, bismuth, lithium, sodium, beryllium, strontium, barium, radium, zinc, cadmium, germanium, molybdenum, tungsten, uranium and cobalt; aluminium, iron and potassium are already partly published, while rubidium, caesium, magnesium, gallium, indium, the rare earths, platinum and a few others are in preparation. The disadvantage of the incompleteness of this work is therefore diminishing fairly rapidly—in 1943 the whole will be finished—but the price may unfortunately deter many individuals and smaller libraries, although there are several degrees of reduction in price for subscribers of the whole work and for members of the German Chemical Society.

However, every chemist who is fortunate enough to have access to a library where the new edition of *Gmelin* is available will probably save much time if he makes it a point to consult it and not to rely on other works. We should advise every one to make a test himself in a subject in which he is specially interested; he will find in *Gmelin* not only a fuller account, but also a more accurate presentation than in any other of the manuals of inorganic chemistry. Nor will the larger number of references make it more difficult for him to find the information wanted. Quite the contrary! While some other authors have simplified their task by quoting together a good many references and leaving it to the reader to find out which one deals with a special point in the text, the enormous wealth of literature collected in *Gmelin* is so carefully correlated to the single

items discussed that in general this feature alone is likely to save the reader a great amount of trouble. Closer comparison with other manuals will probably convince him further that errors and slips, though, of course, not completely absent, are much less numerous than in other well-known reference books which only too frequently rely on second- or third-hand information; while it is one of the most important points in the organisation of the new *Gmelin* edition always to draw from the original sources. A glance for instance at the paragraph in the beginning of each element, on its history—in other works often a deplorably useless repetition of time-honoured inaccuracies, and misprints—will immediately prove that even sources difficult of access have been carefully consulted anew by a member of the *Gmelin* staff.

The great number of forty or fifty competent co-workers enables the editor-in-chief—at first Prof. R. I. Meyer, now Dr. E. Pietsch—to entrust each chapter to a scientist specialising in the subject. The chapters on history, technical preparation, physical properties (especially spectroscopy), electro-chemistry, analytical determination and so on, are written by different people, and so even the comparatively small volume on uranium now under review is due to the collaboration of no less than ten contributors. However, the final editorship of the material is carried out according to strict and well-established rules, and it is much to the credit of the organisation that the whole work makes such a uniform impression. To render every part of the volumes serviceable immediately they come out of the press a preliminary index is published at the same time; and although in some respects *Gmelin* can wish for nothing better than to be regarded as the "Beilstein of Inorganic Chemistry" every one who makes use of it will be pleased to see that, owing to the different character of inorganic and of organic systematics, in *Gmelin* it is much easier to find quickly all the information wanted.

After this general characterisation of *Gmelin's Handbook* we will now say a few words about the special treatment of the two elements under review to-day. While in the case of uranium a single issue could cope with the matter, nitrogen, as one of the most important and most frequently studied elements, was edited in four instalments, thus avoiding delay between the preparation of the manuscript and its publication. It may be mentioned, as a small but helpful detail, that each separate volume gives the exact date up to which the literature on the subject has been completely incorporated; so whoever is going to consult the work knows exactly from what time onwards he has to supplement it by study of later publications. In the fourth nitrogen part, issued in the early summer of 1936, the literature up to March 1, 1936, has been abstracted.

The nitrogen volume comprises so much that it is hardly advisable to select a few topics for discussion, and impossible even to mention all. Its richness is perhaps sufficiently well illustrated if we point out that almost 40 pages are devoted to the biochemical changes undergone by nitrogen in the soil; not less than 13 pages to atomic transformation of the nitrogen nucleus, 26 pages to active nitrogen, 187 to ammonia (the species with heavy hydrogen is not overlooked!), and about 350 to the compounds consisting of nitrogen and oxygen.

The uranium volume presents in 280-odd pages a most up-to-date survey of this element. Its occurrence in the various continents is very carefully described, and a characterisation of all the uranium minerals given. Much

of this information has only recently been acquired, thanks to the modern interest in uranium ores as the raw material for the manufacture of radium. The industrial exploitation of uranium deposits near the Great Bear Lake in Canada is of too recent a date to be included in the volume; but it is a fine proof of the care devoted to the collection of references that this important new development is already foreshadowed by four or five references to the pitchblende which was only discovered in this region during the last few years. As in all similar cases, the shorter-living isotopes of the element are dealt with in the same volume; the radioactive constants of uranium II, of actino-uranium, and even of the artificial uranium isotope which can be produced from thorium by neutron bombardment, are given in full. The volume concludes with a surprise: even the trans-uranium elements are described and all the information available up to now is collected in a table. They are, of course, not isotopic with uranium, but neither are they with any of the 89 elements known to chemists; therefore if ambitious enough to include them in *Gmelin* the editor was certainly right in annexing them to the element from which they are produced.

It may be regretted that the days are over when a single man was able so completely to master the whole subject of inorganic chemistry that nobody would expect an improvement from team work; but nowadays any attempt by one individual to produce a work of reference of the reliability of the new edition of *Gmelin* would be a hopeless anachronism. Chemists of the whole world must be grateful to the German Chemical Society for having put its long experience in literary organisation and publication at the disposal of the editors of *Gmelin*, who, on the other hand, had to be helped financially by Germany's chemical industry to make possible a work of such scope. It is fairly safe to predict that *Gmelin* will find its place in all well-equipped chemical libraries of every country.

F. A. P.

A Comprehensive Treatise on Inorganic and Theoretical Chemistry. Vol. XV. By J. W. MELLOR, D.Sc., F.R.S. [Pp. viii + 816, with 423 diagrams.] (London: Longmans, Green & Co., 1936. 63s. net.)

THE penultimate volume of Dr. Mellor's work deals with the elements nickel, ruthenium, rhodium, palladium, osmium and iridium. The high standard of the previous volumes is fully maintained, the treatment is exhaustive and there is the usual wealth of references. No chemical library worthy of the name can afford to be without Mellor, which is as essential to the industrial chemist as to the academic research worker. Of so well-known and highly appreciated work there is no more to be said.

O. L. B.

Synthetic Inorganic Chemistry. By A. A. BLANCHARD, Ph.D., J. W. PHELAN, S.B., and A. R. DAVIS, Ph.D. Fifth edition. [Pp. xii + 385, with 25 figures.] (New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd., 1936. 15s. net.)

THIS book outlines the entire year's work for both laboratory and classroom as given to the large freshman class at the Massachusetts Institute of Technology. The fact that a fifth edition is called for is sufficient indication of its excellence and popularity. In the new edition special new exercises

and discussions have been introduced and these include such topics as the determination of vapour density and molecular weight, the standardisation of acids and the titration of acids and bases and the use of the pH scale of hydrogen ion concentration. The book opens with some useful notes on laboratory manipulation and then in Chapter I the quantitative aspects of chemistry are dealt with—combining ratios, densities and so forth. Chapter III deals with the ionic theory. The first part of each of these two chapters gives directions for experiments which are performed by the student and the second part of each chapter is devoted to notes discussing the principles that the experiments illustrate and also problems for homework. The other nine chapters are given to preparations and experiments which reveal the properties of the various classes of the chemical elements and their compounds. An outstanding feature of the course is its elasticity. The mediocre student will do the minimum of the set exercises, but his presence will not handicap the competent and enthusiastic worker because to him is open a wide choice of other exercises and preparations. The student who has successfully followed the course outlined in this book will have developed a valuable technique and laid a sound foundation of chemical knowledge. The book should make a wide appeal to teachers.

W. W.

Tungsten : A Treatise on its Metallurgy, Properties and Applications. By COLIN J. SMITHELLS, M.C., D.Sc. Second edition. [Pp. viii + 272, with 183 figures, including 44 plates.] (London : Chapman & Hall, Ltd., 1936. 25s. net.)

THE author of this excellent treatise on Tungsten is a member of the research staff of the General Electric Co., Ltd., and, since the credit for the development of metallic ductile Tungsten must be given to the electrical industry, he is particularly well fitted to write on this subject. Dr. Smithells, whose own contributions to this branch of applied science are very considerable, describes the various processes necessary for the production of thin filaments of a metal which melts at a temperature of well over 3000° C. and which cannot therefore be cast. Tungsten powder, obtained by reduction of its oxide, must of necessity form the starting-point and the subsequent technique used is that of "powder metallurgy," the practice of which is becoming increasingly important in many branches of metallurgical industry. The methods used in promoting the growth of single crystals in tungsten wires for use as non-sagging lamp filaments are particularly interesting since they form an example of the successful commercial application of a technique developed in the course of fundamental investigations on the properties of matter. This book is therefore of the greatest interest to all scientific metallurgists and especially to those concerned with the fabrication of metal from powders.

In this, the second edition, the author, after making some rearrangement of the matter contained in the earlier work, has included the contributions made to the knowledge of the subject during the past ten years. He has also met the only criticism which could be put forward of the earlier work by handing over the sections dealing with alloys of Iron and Tungsten and Hard Alloys of Tungsten Carbide to Mr. J. H. G. Monypenny and Mr. T. R. Bird respectively. As recognised authorities on these particular branches of the subject, their scholarly contributions are in keeping with the remainder of the book. A notable addition is a chapter on Thermionic Emission by Dr. A. L. Reimann.

Full references to other published work are made throughout the text and the book is adequately indexed. In all respects the production of the book maintains the high standard set in the original edition.

E. A. G. L.

Industrial Chemical Calculations. By O. A. HOUGEN, Ph.D., and K. M. WATSON, Ph.D. Second edition. [Pp. ix + 487, with 97 figures.] (New York : John Wiley & Sons, Inc. ; London : Chapman & Hall, Ltd., 1936. 22s. 6d. net.)

In this very useful book certain important principles of chemistry and physics have been selected for detailed study, the significance of each principle being developed and its applicability and limitations considered. The application and combination of these principles are illustrated by detailed solutions of typical problems selected to represent, wherever possible, actual conditions which are met with in practice. In the accompanying calculations, care is taken that the reasoning is logical and apparent, and the authors have spared no pains to ensure that their method of presentation is both intelligible and authoritative. Moreover, in order to permit of a thorough appreciation of fundamental principles and to discourage superficial memorising, the treatment of each subject commences with a statement of the elementary concepts concerned, a method which is well justified even at the risk of duplication of some of the material to be found in text-books of physical chemistry, and one which should prove extremely valuable to industrial engineers who possess a limited knowledge of chemistry. The primary object of the book is to supplement the usual course in physical chemistry and to help the student intended for industry to bridge over the difficult transition period. The authors have made no attempt, therefore, to discuss the unit operations of chemical engineering or the more specialised studies of chemical engineering design, which properly belong to advanced courses in this subject.

During the five years following the first edition, the chemical engineering profession has progressed rapidly in the development of quantitative methods of treating its problems ; at the same time, these problems have tended to become more complex with the increasing application of high temperatures and pressures, and in the volume under review extensive changes have been made in order to keep pace with these requirements. Thus, the thermodynamic approach to problems involving non-ideal conditions has been advanced to practical utility and it is essential for the chemical engineer to be familiar with such methods. This has led to the introduction into the present volume of the concepts of entropy, free energy, fugacity and activity, together with the applications of these to industrial problems, and to the replacement of the kinetic theory approach to the principles of equilibrium by more concise thermodynamic methods. In consequence, a complete reorganisation of the text has been found necessary, and the first part of the book is now limited to treatment of ideal, low-pressure systems in which simple algebraic methods can be employed, whereas the second part deals with non-ideal cases by more general methods involving considerable use of the calculus.

A section devoted to conversion units has been added to the first chapter, and the use of weight and heat balances has been given more prominence in the early chapters than in the previous edition. Throughout the entire book emphasis is placed on generalised methods for predicting the missing physico-chemical data which hamper almost every industrial problem. Thus,

in Chapter VII new methods are given for estimating the combustion properties of petroleum fuels, and in Chapters XI and XIII are to be found generalised methods for estimating compressibility factors, fugacities, enthalpies and heat capacities in the absence of specific data. Chapter VIII, which deals with heat and weight balances in combustion processes, has been rewritten in a manner consistent with the general rearrangement of the text, viz. to start with the most simple cases and to lead from them to the more complex. The chapter in the first edition on distillation equilibria has been omitted, since the subject matter was considered more appropriate to a textbook of chemical engineering proper.

This book should prove of great value, not only as a preliminary to an advanced course in chemical engineering, but equally so to chemists and engineers already in industry in enabling them to develop a better appreciation of the processes which they are called upon to operate and control.

H. W. CREMER.

Miners' Safety Lamps: Their Construction and Care. By T. R. BARNARD, B.Sc.Tech., A.M.I.Min.E., M.A.M.E.E. [Pp. xii + 88, with frontispiece and 17 figures.] (London: Sir Isaac Pitman & Sons, Ltd., 1936. 4s. net.)

THERE is no branch of engineering where lighting is of greater importance than it is in mining engineering. In the mine not only is artificial light necessitated by the very conditions, but the special considerations of safety also loom large and govern the designs of lamp; reflection, particularly in coal mines, is deplorably low; and nystagmus is a heavy financial burden on the industry—to say nothing of the actual suffering involved.

The material included in this little book is, in the main, definitely good. There is a brief but sound historical introduction: justice is done to the work of Wheeler and Woodhead on flame lamps: electric hand- and cap-lamps are treated thoroughly: and the chapters on special lamps and lamp-rooms, illumination and photometry are satisfactory, as far as they go. As, however, abstracts from the Coal Mines General Regulations (Lighting) 1934 and Mines Department Testing Memorandum No. 1 occupy pages 73–81 and there is in addition a bibliography of four pages, it will be seen that the author has attempted to compress into seventy pages (some occupied entirely with diagrams) an unwieldy amount of material. One is left with the feeling that a broader canvas was really called for.

There is, no doubt, a certain demand among mining students for a booklet on Mine Lamps, and the work under review supplies this need; but it is earnestly to be hoped that sooner or later the proper study of Lighting and Illumination (preferably on the lines laid down by Trotter in his original work) will be undertaken by those who aim at making really useful contributions towards the improvement of underground lighting conditions. The real value of this booklet is that it may whet the appetite for such study, and, if so, it will have done good service. There is much looseness and ignorance on the part of engineers and scientists (of various ranks) on lighting and its problems, and nowhere is careful and serious study more urgent than it is among the mining community. The subject is by no means simple.

The price of the book, 4s., seems high.

J. W. W.

Recent Advances in General Chemistry. By S. GLASSTONE, Ph.D., D.Sc., F.I.C. [Pp. x + 430, with 25 figures, including 2 plates.] (London : J. & A. Churchill, Ltd., 1936. 15s. net.)

THE title of this book rather belies its contents. It is a companion volume to the author's *Recent Advances in Physical Chemistry*, and without exaggeration might be called Volume II of the latter work. The contents, however, cover a wider range from Atomic Disintegration on the one hand to Organic Free Radicals on the other. It will therefore appeal to the general reader in chemistry though the topics are essentially physico-chemical in character.

The book opens with a chapter on atomic disintegration, the history of the discovery of the neutron and the positron finding a place here. Almost half the chapter is rightly devoted to an account of artificial radioactivity, for the use of radioactive indicators in solving purely chemical problems has already begun and promises to become a fruitful field in the near future. Next follows a chapter on statistical methods in which there is a clear exposition of the methods of utilising statistical mechanics along with spectroscopic data for the calculation of the entropy of molecules and therefrom the equilibrium constants of chemical reactions.

Ortho- and Para-Hydrogen and Deuterium follow naturally in the next two chapters. These are both rapidly growing fields of work, but in the short compass of 90 pages sufficient is given to indicate how parahydrogen and deuterium may be applied to elucidate chemical problems. Somewhat surprising but none the less useful is a chapter on the determination of molecular structure by the application of electron diffraction to gases and vapours. The chapter on Kinetics of Reactions in Solution is likewise thoroughly up to date. Even so recently debated a subject as the transition state method is given a full discussion. Two chapters, namely Solubility and Acid-Base and Salt Catalysis, are transferred from *Recent Advances in Physical Chemistry*. Finally, to conclude the book there is a well-balanced chapter on Simple Organic Free Radicals. This is a subject upon which a great deal has been written recently. Some of the work is unfortunately of doubtful validity, and for those not thoroughly conversant with the subject difficult to assess at its true value. In such cases Dr. Glasstone carefully withholds judgement.

There is only one criticism. By gathering all the references together at the end of the chapter, it is often rather difficult to trace the origin of a statement of fact or a table of figures given in the text. Since the book is likely to be thumbed by active workers in physical chemistry, a more convenient way of quoting references would expedite the location of original papers.

The arrangement of such a book is largely a matter of personal preference, and though some would curtail certain chapters and extend others, it must be recognised that taken together these two volumes give an excellent and well-balanced outline of modern physical chemistry. It would be unfair, therefore, to pick out small points for criticism when such an enormous field is covered by one writer.

H. W. MELVILLE.

Recent Advances in Physical Chemistry. By S. GLASSTONE, Ph.D. D.Sc., F.I.C. Third edition. [Pp. viii + 477, with 31 figures.] (London: J. & A. Churchill, Ltd., 1936. 15s. net.)

THAT a third edition of this well-known work is called for in so short a time—the first edition was published in 1931—is the best proof of its wide acceptance by the chemical public. The new edition also serves to demonstrate how quickly the subject extends. Indeed, the extension has been so great that Dr. Glasstone has wisely refrained from increasing the size (and price) of his book and has instead produced an equally acceptable companion volume, *Recent Advances in General Chemistry*, which is reviewed above.

The main addition is a section in the chapter on the electronic theory of valency on the applications of quantum mechanics to chemistry. This is essentially non-mathematical in character, but is not wholly descriptive, thus satisfying the reader who is more interested in the direct usefulness of the methods to chemical problems. Brief descriptions are given of the Heitler-London and the orbital methods of calculating the energy and configuration of molecules. There is also a short and clear exposition of the term resonance, about which there has been some misunderstanding between chemists and physicists. Each chapter has been brought up to date, papers appearing a few months before publication of the book assuming a rightful place in many of the chapters. The chapter on Acid-Base and Salt Catalysis has been transferred to the companion volume to make way for additional material.

H. W. MELVILLE.

Physical Chemistry. By F. H. MACDOUGALL, M.A., Ph.D. [Pp. x + 721, with 97 figures.] (New York and London: Macmillan & Co., Ltd., 1936. 17s. net.)

THIS volume reflects the changes which have come about in recent years in writing introductions to physical chemistry. In the older text-books, thermodynamical proofs, the structure of the atom and other topics were relegated to a few chapters at the end of the book, to be read after the first course in physical chemistry is completed. Nowadays it is necessary to incorporate these matters to form a more homogeneous text. The selection and arrangement of modern material is an extremely difficult task and authors' opinions are still widely divided. Prof. MacDougall has, however, produced a work in which modern physical ideas are blended judiciously with the older chemical topics of physical chemistry. The first four chapters deal with the first law of thermodynamics, the gas, liquid and solid states in the usual manner. Then follow two chapters on the structure of the atom in which there are accounts of X-ray and optical spectra, quantum theory of radiation, radioactivity, isotopes. Next a return is made to more physico-chemical themes, the parachor and dielectric constant finding a place here. A chapter on the Second Law of Thermodynamics prepares the student for discussions on solutions, equilibria, electromotive force. For those students who can digest it, an outline of the Debye-Hückel theory is also included. Finally, there is a chapter on Photochemistry and one on Colloids which seem to lie outside the framework of the book and are indeed difficult to incorporate in any predetermined scheme. Questions are given at the end of each chapter. Answers to the numerical examples would be welcome.

As a first book in physical chemistry, especially for students who only desire a working knowledge of the subject, some sections are rather advanced and the teacher will therefore have to exercise some discrimination in directing the reading of his students. For those specialising in chemistry, however, this book will make for a smooth transition from the introductory text to the specialist monograph.

H. W. MELVILLE.

Organic Syntheses. Vol. XVI. JOHN R. JOHNSON, Editor-in-Chief. [Pp. vi + 104, with 3 figures.] (New York : John Wiley & Sons, Inc. ; London : Chapman & Hall, Ltd., 1936. 8s. 6d. net.)

THIS volume follows the lines of the previous ones. The methods described for the preparation of the compounds in the laboratory have been fully tested and can be relied upon to give the yields stated. The compounds of which the preparation is given in detail are β -alanine, 4-aminoveratrole, *n*-butyl nitrite, *n*-butyl phosphate, diphenylbisazo-1-amino-8-naphthol-2 : 4-disulphonic acid (a salt-free azo-dye), *sym*-dimethylhydrazine dihydrochloride, *unsym*-dimethylhydrazine hydrochloride, 2 : 5-dimethylpyrrole, 1 : 4-diphenylbutadiene, epichlorohydrin, epibromohydrin, ethylphenylmalonate, ethyl *n*-tridecylate, *n*-heptoic acid, *n*-hexylaldehyde, isonitrosopropiophenone, methyl benzyl ketone, methylhydrazine sulphate, *p*-nitrobenzyl bromide, 4-nitrophthalic acid, 4-nitrophthalimide, pelargonic acid, phenanthrene 2- and 3-sulphonates, phthalaldehyde acid, phthalide, quinone, succinimide, tetrahydrofuran, *sym*-trithiane.

Perhaps attention might be drawn to the possible toxic properties of the alkyl hydrazines. A colleague of the reviewer working with these compounds a number of years ago exhibited disturbing symptoms in the form of heart trouble. The investigation was stopped and the symptoms ceased and have not recurred. Though there was no proof they were due to alkyl hydrazines they were sufficiently serious to raise suspicions of the effect of these compounds, especially in view of the known toxic properties of phenylhydrazine to which some individuals show a dangerous susceptibility.

These volumes are a necessity to the organic research chemist, and can be recommended without reserve owing to the reliability of the methods described.

O. L. B.

Outlines of Organic Chemistry. By E. J. HOLMYARD, M.A., M.Sc., D.Litt., F.I.C. Second edition. [Pp. xii + 468, with 6 plates and 39 figures.] (London : Edward Arnold & Co., 1936. 7s. 6d.)

EVEN in days when electronic conceptions of valency are accepted it still requires initiative to introduce their consideration into a text-book. The author has shown his enlightened outlook by including an excellent chapter on Valency, developed from electronic ideas. He uses the octet cube, didactically defensible, but warns the omnivorous and uncritical student with the statement, "It is no longer assumed that the electrons are situated at the corners of cubes, but Langmuir and Lewis's theory is still accepted in its essentials," and then neither leaves the student wondering what those essentials are, nor, worse still, goes beyond the scope of his book and hopelessly "fogs" him with a curt and inadequate "explanation," but indicates the source of enlightenment—Prof. Sidgwick's *The Electronic Theory of Valency*, which, everyone will agree, has become "a classic of chemistry."

The other chapters on theory at the beginning of the book are also excellent, not only in material but in the interest-compelling presentation. But one cannot help thinking that proper understanding of these chapters is only possible after acquisition of the later portions of the book. Several portions should have been at the end, if not in Appendices, *e.g.* the proof of the equivalence of the 4 hydrogen atoms of methane (pp. 121-4). Again in the very up-to-date chapter on Stereoisomerism—the most concise yet clear summary available in any text-book—the question arises as to whether it is advisable in an attempt to be comprehensive to include work which, without lengthy explanation, is incomprehensible to the student, *e.g.* (p. 95) the brief reference to "Asymmetry may also arise from restricted rotation about a single bond" (formula given, etc.), although neatly put, is, without further explanation, only a difficult cross-word puzzle to the conscientious reader.

The chapters on structure and calculation of formulae are very lucid and helpful. The sections on the "Constitution of the Ethylene Molecule" (pp. 176-9), and "Structure of the Benzene Molecule" (pp. 350-61) are outstanding.

Technical uses of compounds are given without unnecessary detail, and provide the student with incentive to study such compounds. The most curious academic curiosity is far less interesting to the average student than the least useful industrial application. The inclusion of recent work makes the book a very modern one, *e.g.* the mention of free radicals (p. 108), uses of acetylene, preparation and properties of chlorinated hydrocarbons (p. 187), sodium methide (p. 55), catalytic methods generally; and the introduction of a little humour in reference to glacial acetic acid (the chemist's cuckoo) (p. 50) and the medicinal use of nitroglycerine (p. 224) reminds us that from the springtime of life till arterial sclerosis sets in we are human although chemists.

As in every book there are a few omissions and discrepancies: the "Oven for Carius Tubes" (p. 40) is crude, *e.g.* there is no place for a thermometer; the description of simple laboratory processes in Chapter II could quite well be left to the Practical Text-books; the formulae for semicarbazones (pp. 276, 384, 386) are wrong; the catalytic use of V_2O_5 in the aero-oxidation of naphthalene to phthalic anhydride (p. 448) should scarcely have been omitted.

Historical references are mercifully brief.

This book will delight the teacher and inspire the student.

S. HORWOOD TUCKER.

Essential Principles of Organic Chemistry. By C. S. GIBSON, O.B.E., M.A., Sc.D., F.R.S. [Pp. viii + 548, with 38 figures.] (Cambridge: at the University Press, 1936. 18s. net.)

TEACHERS of organic chemistry are always being asked by their students what book to use, and they have had misgivings, for some of the text-books were first compiled and then padded from one edition to another, and some leave untouched certain important aspects of this unwieldy branch of chemistry. Prof. Gibson has produced a volume which will have considerable appeal, and the assimilation of which will give a student a useful grounding in the subject. Stereochemistry is made to creep in wherever it can, and this is an excellent thing from every point of view. The reader is told where interesting compounds come from and how important ones are manufactured.

The synthetic methods of organic chemistry are well illustrated by sound examples.

The orientation rule of Crum Brown and Gibson is given its proper perspective and not rejected as it often is. The carbohydrates are very thoroughly dealt with. The historical side of the subject is not made oppressive as it sometimes is.

It is difficult to understand the author's departure from customary nomenclature in a few instances, although no doubt *p*-aminobenzenearsonic acid (p. 270) and *phenyldiazonium* chloride (p. 274) are better names than the ones most of us use. Sodium phenate and phenyl iodide should not, however, be used for sodium phenoxide and iodobenzene. The last formula for benzene given on p. 62 will probably confuse the beginner rather than help him. The mechanism given on p. 302 for the Skraup reaction is not that usually accepted, and the use of pressure in the Kolbe salicylic acid synthesis should be attributed to Schmitt. Such minor defects, however, are hardly avoidable in a book of this kind, and they will without doubt be corrected in the second edition, for which one can expect a demand as soon as the volume becomes known.

E. E. TURNER.

Elementary Practical Chemistry. By A. I. VOGEL, D.Sc., D.I.C., F.I.C. [Pp. 220, with 73 figures.] (London and Glasgow: Blackie & Son, Ltd., 1936. 3s.)

THIS laboratory manual is intended for the use of students who have no previous experience of the subject, and it covers the practical work up to School Certificate standard. The experiments are interspersed with sufficient theory to make the work intelligible, and hence the book is a great improvement on the "recipe" type. It is not designed to take the place of a textbook, but rather to avoid the difficulty of personal instruction when large classes are using the laboratory. Many of the experiments described would have to be carried out as demonstrations in most schools, but that does not detract from its value, for it allows of its use in those institutions where there is more opportunity for individual work.

The book is very comprehensive, containing useful data, logarithmic tables, and a chapter on the treatment of accidents. Its outstanding virtue, however, is the emphasis it places on simple quantitative work.

E. D.

GEOLOGY

Memoir on Fossils of the Late Pre-Cambrian (Newer Proterozoic) from the Adelaide Series, S. Australia. By SIR T. W. EDGEWORTH DAVID, K.B.E., D.Sc., Sc.D., F.R.S., and R. J. TILLYARD, M.A., Sc.D., D.Sc., F.R.S. [Pp. xii + 122, with 14 plates and 1 figure.] (Sydney: Angus & Robertson, Ltd., 1936. 7s. 6d.)

THE Memoir with the above title gives the history of the discovery and interpretation of the forms from the Teatree gully quartzite north of Adelaide. Those who had the honour of knowing Prof. David will realise how his unbounded enthusiasm carried all before it. For many years he had been searching the Adelaide series of Pre-Cambrian rocks for traces of life, which he felt sure would eventually turn up in them.

His vast field experience must be taken into account, and, moreover, he states that, "he has very specially guarded against the danger of mistaking for organic remains purely inorganic concretionary matter." His claim that the forms here described are of organic matter must, therefore, receive due consideration, especially as we read on p. 2 that "no Australian scientist . . . who has taken the trouble to study the specimens has any doubt whatever as to their being genuinely organic."

Unfortunately, this view is not held by the majority of scientists in this country who have seen some of the specimens.

It is also unfortunate that the photographs of the specimens figured in this Memoir are reproduced on a rather coarse half-tone screen, for the evidence to be derived from their study alone appears to be insufficient to justify the reconstructions given. For instance, the bilateral symmetry, of which much is made, is far from obvious on the photographs, and there appears to be a somewhat arbitrary selection of fragments for inclusion as part of the organism. There are some pieces which are apparently discarded, which look just as good as others which are labelled as being definite parts of the organism. The photographs also show small sign of the segmentation which is represented by the labels A_1 to A_6 .

If, however, we admit the given reconstructions, then Dr. Tillyard's analysis of the status of the form may be justified, but the gap between the photographs of the specimens and the reconstructions seems so great that palaeontologists in this country must be permitted to remain sceptical until they have seen the material which apparently convinces the Australian scientists.

Some may deprecate the publication of this work, but surely it is well that the views of the authors should be placed on record, so that future workers may be able to know the evidence they relied upon and the conclusions to which they came.

W. B. R. K.

Rutley's Elements of Mineralogy. By H. H. READ, D.Sc., A.R.C.Sc., F.G.S. Twenty-third edition. [Pp. viii + 490, with 128 figures.] (London: Thomas Murby & Co.; New York: D. van Nostrand Co., 1936. 8s. net.)

PROF. READ's first revision of Rutley's Elements of Mineralogy formed the nineteenth edition published in 1915. With this twenty-third edition, which testifies to the extreme usefulness of the work, the book has been thoroughly revised and reset with new illustrations, and Prof. Read has therefore been free to rewrite and rearrange the whole of the subject-matter. In Part I, "Properties of Minerals," the main changes are that the chapters on Crystallography and Optical Properties of Minerals have been completely rewritten and enlarged, and that a chapter on the Occurrence of Minerals has been added, the information in which was formerly given in the glossary.

In Part II, "Descriptions of Minerals," a new grouping of minerals has been adopted. A combined economic and chemical classification is used, first grouping the minerals according to the useful element contained in them, and then arranging the elements according to the Periodic Classification. One result of these changes is a considerable increase in the size of the book; another is an augmentation of its value, especially in the chapters on crystallography and optical mineralogy; and as the metamorphosis of

Rutley into Read is now all but complete, the work has also gained in unity. This book still stands alone as the best British work on mineralogy for students of geology.

G. W. T.

The Geological Map. By KENNETH W. EARLE, D.Sc.(Lond.). [Pp. viii + 96, with 41 figures.] (London: Methuen & Co., Ltd., 1936. 3s. 6d.)

In spite of its small size, this book is very thorough and omits nothing of importance to the ordinary student of geology. The language is simple and, though descriptions are condensed, they are usually clear enough for the beginner to follow if he takes pains. The sequence of the chapters is a natural one leading from the simpler to the more complex problems of structure. Probably the most valuable chapter is the last and longest, consisting of descriptions of nine representative geological maps, mostly from the Geological Survey series, which are models of terse yet searching analyses of typical areas. There are many references in earlier chapters to special sheets, in illustration of the structures being described therein. The low price does not permit of any reproductions of actual geological maps, but this cannot be regarded as a defect from the point of view of the real student.

The author has succeeded in his aim of producing a cheap and handy guide to the study of geological maps and the reviewer can find no fault with the text, except for a few minor errors. It is a great pity, therefore, that the illustrations are not of a similar high standard, for it is almost as easy and just as cheap to produce good diagrams as bad. The block diagram method is an ideal one for showing the structures in three dimensions, but they must be neatly drawn and must give the effect of perspective. Neither of these requirements is really fulfilled in the majority of the block diagrams, and in some cases they obscure rather than elucidate the excellent text descriptions. The reviewer regrets that he must make this stricture, but the book is in every other way so excellent that he urgently hopes that later editions will amend this one real fault.

F. D.

BOTANY AND AGRICULTURE

Diseases and Pests of the Rubber Tree. By ARNOLD SHARPLES, A.R.C.Sc., D.I.C. [Pp. xviii + 480, with frontispiece, 4 coloured plates, 70 figures and 11 diagrams.] (London: Macmillan & Co., Ltd., 1936. 25s. net.)

THE author of this comprehensive and well-illustrated manual is specially competent to deal with the diseases and pests of *Hevea brasiliensis*. As Government Mycologist in the Federated Malay States and, later, as head of the pathological division of the Rubber Research Institute of Malaya, he has given many years to the study of rubber diseases in the East.

His claim that all expenditure on pathological work in Malaya has been repaid many times over is justified, but there is still much to learn. Many of the control measures successfully adopted as each new wave of disease assumed importance were based on half-truths; they can be cheapened and made more effective as further knowledge is acquired. This is especially evident in the account given of the formidable group of root diseases which occupies nearly half the book: a subject which the author and his colleagues

at Kuala Lumpur have made peculiarly their own. The history of the efforts to control these diseases, from the first crude attempts by trenching and liming, is one of tracing them backwards from the dead rubber tree to their origin from pre-existing foci of infection in the jungle on whose site the plantation was established. The identification of these foci and their eradication at the earliest practicable moment opens a new path in root disease control in permanent crops ; but there is still a long way to go.

The book is discursive and meant for planters to dip into here and there when troubles appear. Nevertheless, it will repay careful study by tropical plant pathologists. It is marred by errors from careless proof reading which should be corrected in any subsequent reprint. On p. 23, Fig. 8 (d) and Fig. 10 should be Fig. 9 (d) and Fig. 11. *Ganderna* is printed for *Ganoderma* on p. 25, *Hemeleia* for *Hemileia* (p. 27), *Ascoshyta* for *Ascochyta* (p. 28), *Cicinnobilis* for *Cicinnobolus* (p. 300). But these are minor faults in a book which is a worthy companion to the other well-known manuals on tropical and sub-tropical agriculture published by the same firm.

E. J. BUTLER.

Fifty Years of Field Experiments at the Woburn Experimental Station. By SIR E. JOHN RUSSELL, D.Sc., F.R.S., and Dr. J. A. VOELCKER, C.I.E., M.A. With a Statistical Report by W. G. COCHRAN, B.A. The Rothamsted Monographs on Agricultural Science. [Pp. xvii + 392, with 4 plates and 42 figures.] (London, New York, Toronto : Longmans, Green & Co., 1936. 21s. net.)

THE WOBURN Experimental Station was founded jointly by the Duke of Bedford and the Royal Agricultural Society in 1876 as the direct outcome of the passing of the Agricultural Holdings Act in 1875 whereby the giving of compensation to an outgoing tenant for the unexhausted value of purchased food was made a subject for arbitration. One of the chief problems for investigation was, therefore, to ascertain to what extent the productiveness of the soil was influenced by the feeding of concentrated foods, such as cake or corn, to the livestock on the farm. This problem proved to be more difficult than had been anticipated and after sixty years of experiment it remains uncertain whether any rigid basis of compensation can be drawn up. Notwithstanding this, valuable information has been obtained about the effects of soil and climatic conditions on the effects of fertilisers and manures on plant growth. Experiments on green manuring to test the value of tares and mustard as preparation for wheat led to the conclusion that no beneficial effect was produced on the crop. By the application of modern statistical methods to the experimental data much valuable information has been extracted. Among the more important conclusions and deductions are : (1) The general need for nitrogenous fertiliser whether the soil be light or heavy ; (2) the need for lime when sulphate of ammonia is used frequently ; (3) the fact that green manuring is by no means a trustworthy practice, but is liable to break down badly even on soils where it would be most expected to do well ; and (4) that serious losses are incurred in using farmyard manure and in folding cake on the land.

The book, which opens with an Introduction by Sir E. J. Russell from which the above summary has been drawn, is divided into 4 parts of which the first is by Dr. J. A. Voelcker ; this consists of some 112 pages in which the experiments are described ; the second part by Mr. Cochran deals with

Statistical examination of the results, while the third part, which describes the bearing of the results on agricultural science and practice, is by Sir John Russell. Part IV on the soils of the Woburn Plots, by Dr. E. M. Crowther, contains valuable data and describes in detail the analytical methods employed for the determination of exchangeable calcium, readily soluble phosphoric acid, pH values, etc. An appendix of some 40 pages contains a number of numerical tables regarding crop yields from the year 1878 and onwards. The book contains a great deal of interesting reading and well maintains the high standard one is accustomed to expect from the Rothamstead Monographs under the general editorship of Sir John Russell.

P. H.

English Farming, Past and Present. By the RT. HON. LORD ERNLE, P.C., M.V.O. Fifth edition. Edited by SIR A. D. HALL, K.C.B., M.A., F.R.S. [Pp. xvi + 559.] (London, New York, Toronto: Longmans, Green & Co., 1936. 15s. net.)

LORD ERNLE's book has been for twenty-five years the standard text on the History of English Agriculture and is indispensable to any serious student of the subject. Sir Daniel Hall's solution of the difficult problem of revision has been to leave the old text substantially unaltered and, in three new chapters, to give a complete and down-to-date account of the main developments of the post-War period.

One could indeed have wished for a more complete revision. The first chapter of the book, for instance, was scarcely adequate when it was written, for it brings us to A.D. 1300 in the space of 30 pages. Many of the views expressed in the chapter are now seriously out of date. The text reads as if one might still take seriously the view of Seeböhm about the origin of the Manor, according to which the manorial farm was the direct descendent of the Roman Villa; whereas, in fact, there is scarcely a single record of the finding of early Saxon remains on a Villa site. Again we are given no more than a footnote to correct the impression left by the text that the typical three-field lay-out of the Midland Village Farm was the standard early form of rural organisation throughout the whole country. The point is not unimportant, because an understanding of the early forms of settlement is essential to that of the enclosures, and even as a key to the present-day lay-out of our villages and fields.

Sir Daniel's own additions to the book are excellent in themselves. There is an admirably balanced, accurate and fair account of the highly controversial subject of land settlement and small-holdings. On the other hand, Lord Ernle's original picture of the farm labourer has been allowed to stand, and the very substantial rise in his wages and the all-round improvement in his status, which have occurred in the last twenty years, are ignored. There is an excellent chapter on recent developments in the field of Education and Research, and the account gains greatly in interest from the fact that Sir Daniel Hall was himself largely responsible for the building of the organisation that he describes. The final chapter on "Technical Progress since the War" is not only good in itself but helps to correct a fault in the earlier editions—that they told us perhaps too much about the economic vicissitudes of farming and too little about the progress of science and technique.

The production of the book does scant justice to its distinguished authorship. The type has an antiquated look and is none too easy to read. The

page is unattractive and the binding is not calculated to stand up to re-reading and continual use for reference. The agricultural student has often a scientific rather than an historical bent and takes a little unkindly to historical studies. A few good illustrations and a more attractive format would make a helpful sugar-coating to his pill.

J. A. S. W.

ZOOLOGY

Neuroembryology: An Experimental Study. By SAMUEL R. DETWILER. [Pp. xii + 218, with 107 figures.] (New York and London: Macmillan & Co., Ltd., 1936. 16s. net.)

IN this volume, one of the first of the new American Experimental Biology Series, Prof. Detwiler has collected the results of experimental investigations into the development of the vertebrate nervous system. Few writers are as competent as he for such a task, for during the past twenty years he has contributed forty papers on this subject. In addition to his own work dealing with the agents concerned in directing the outgrowth of nerve-fibres, the behaviour of grafted limbs, cellular proliferation in the neural tube and dorsal root ganglia, and many other problems, Prof. Detwiler deals with the work of other neuroembryologists such as Ross, Harrison, Coghill, and Weiss, to mention only a few. The result is an invaluable manual which no embryologist or neurologist can afford to miss.

There is a great future for experimental investigations in vertebrate embryology, a field in which morphological knowledge is sufficiently advanced to enable critical experiments to be devised, performed, and interpreted. That such knowledge is essential for profitable experimentation is amply illustrated by Prof. Detwiler's book. There is, however, a small point which calls for criticism. It is found that removal of the mesodermal somites from an embryo of *Amblystoma* at the very early tail-bud stage does not prevent the formation of a normal limb. From this it is concluded that "presumably in all classes of Vertebrates the limb musculature arises from unsegmented mesoderm" (p. 151). A study of Selachian embryos would soon show that this statement is invalid. Besides which, the notion of the formation of a limb, with its striated, voluntary muscles, innervated by many segmental ventral nerve-roots, from unsegmented and therefore presumably visceral mesoderm, would contradict everything so far known about the morphology of vertebrate mesoderm. It is more economical of hypotheses, therefore, to interpret these experiments by assuming that the contributions of the somites to the limbs are very precociously segregated, so that the formation of discrete and segmental "muscle-buds" is obscured or no longer occurs.

The book is most attractive in every way, and we look forward with eagerness to the next volumes of this excellent series.

G. R. DE BEER.

Elementary Morphology and Physiology for Medical Students.

By J. H. WOODGER, D.Sc. Second edition. [Pp. xii + 498, with 255 figures.] (London: Oxford University Press, 1935. 12s. 6d. net.)

A DOZEN years have elapsed since the first edition of Dr. Woodger's book which, with its many original illustrations and its novel presentation of the

subject-matter, is one of the most attractive introductions to animal biology. This edition conforms closely to the last, except for the terminal chapter which the author has rewritten, and which gives an admirable presentation of theoretical biology to the beginner. Of all elementary text-books of zoology, this one, cast in a mould of consistent logical and conceptual schemes with a philosophical background always kept in mind, its attention to strict verbal accuracy and lucidity, is surely the most educative and satisfactory. The only difficulty which teachers and students may experience will perhaps lie with the syllabus to which they may be working, for Dr. Woodger devotes few pages to the higher invertebrates. The small amount of extra information which they might require could, however, easily be obtained elsewhere, while it would be necessary to look far to obtain a better presentation than Dr. Woodger's of the essentials of animal biology for medical students.

G. R. DE BEER.

Forest Insects. By R. W. DOANE, E. C. VAN DYKE, W. J. CHAMBERLIN and H. E. BURKE. American Forestry Series. [Pp. xii + 463, with frontispiece and 234 figures.] (New York and London: McGraw-Hill Publishing Co., Ltd., 1936. 25s. net.)

THE fact that this book has come under review in this country together with the statement on the title-page that it is a text-book for the use of Students in Forest Schools, Colleges and Universities and for Forest workers suggests that it is not written exclusively for Americans. Having first examined it with this in mind, I have satisfied myself that, although the general principles of control will be useful on this side of the Atlantic, the insects referred to and figured in the text are American and, excepting some systematic works and a few others, the literature cited in the bibliographies is American also.

This does not mean that the book is useless here, but its uses are limited to a much greater extent than, for instance, an English or American Text-book of Entomology, where reference to English or American types is of less importance than the rest of the book.

There are a number of unfamiliar names of genera in the book, such as *Adelges* and *Pineus* for the old well-known name *Chermes*, *Cinara* for *Lachnus*, etc. In a book of this type, the authors have to use some system of classification for each of the Orders of Insects they discuss and it would have been useful if they had indicated for each Order whose system they were following.

FRANK BALFOUR BROWNE.

A Monographic Revision of the Genus "Ceutophilus" (Orthoptera, Gryllacrididae, Rhaphidophorinae). By T. H. HUBBELL. [Pp. 552, with 39 plates and 3 figures.] (University of Florida Publication, Biological Series, Vol. II, No. 1, 1936. \$3.75.)

THE genus *Ceutophilus* Scudd. belongs to the group Rhaphidophorinae which includes wingless insects known in America as cave-crickets and camel-crickets. It has been revised by Scudder in 1894, but the necessity of a new revision has been felt for some time and this laborious task was accomplished by the author in a most impressive manner. Over 17,000 specimens were examined and all known and new species described in great detail, not only from the morphological point of view, but also with regard to their ecology, bionomics and distribution. A clear and very precise key for

identification of each species is given, and numerous excellent figures of morphological details should make the determination certain and not difficult.

The book represents a masterly monograph of a most difficult group, while the concluding chapters dealing with the phylogeny and evolutionary history of *Ceutophilus* deserve the close attention of every biologist interested in North American fauna.

B. P. UVAROV.

Herdmania. By S. M. DAS, D.Sc. The Indian Zoological Memoirs, No. V. [Pp. x + 103, with 64 figures.] (Lucknow: Lucknow Publishing House, 1936. Rs. 2.)

THIS monograph on the common Indian simple Ascidian is a worthy addition to the series edited by Prof. K. N. BAHL, and should be of great value. The Indian series fulfils the function performed in this country by the memoirs of the Liverpool Marine Biological Committee, and deserves every encouragement.

G. R. DE BEER.

Inheritance and Evolution. By W. F. WHEELER, M.A. With a Foreword by E. B. FORD, M.A., B.Sc. [Pp. xii + 116, with 39 figures.] (London: Methuen & Co., Ltd., 1936. 3s.)

THIS little book will have its uses as a brief and elementary summary of some of the modern work in genetics, but it is written almost entirely from the zoological point of view. It gives brief statements of such topics as Mendel's Laws, mitosis and gametogenesis (which is not clearly distinguished from meiosis), the chromosome hypothesis, mutations, adaptations, Lamarckism and the neo-Darwinians. For school readers and others who require a brief treatment the book has value.

A few criticisms may lead to improvements in a later edition. The drawing of an ovule (Fig. 1) is unsatisfactory and should be replaced by one in which the cells are correctly drawn. The diagram in Fig. 10 is not very illuminating. In Figs. 26-28 the letters used are so much alike that the result is obscure. The treatment of mitosis and meiosis is modernised, but it can no longer be safely assumed without qualification that chromomeres exist as they are commonly figured.

R. R. G.

Biological Time. By LECOMTE DU NOÛY. [Pp. x + 180, with 31 figures.] (London: Methuen & Co., Ltd., 1936. 7s. 6d. net.)

PHILOSOPHERS have only recently, and with some difficulty, outgrown the idea that time essentially consists in a series of particular instants, and, since time is measured by the recurrences of certain physical processes such as the rotation of the earth, it is still usually thought of as something external and given, to which man has to adjust himself. All biological organisms, however, are subject to intrinsic sequences of happenings, which might be used to define an internal time proper to the organism in question. Lecomte du Noüy draws attention to two such variables, the rate of healing of wounds and the growth-promoting properties of the blood plasma, both of which change gradually during life and can therefore be used to define a "true" or physiological age as opposed to the merely physical age measured by the rotations of the earth round the sun. There are, of course, a host of

other such gradual changes which could be used similarly, and it may be suggested that a "true" internal time should refer to all these changes together, rather than to one arbitrarily selected one; a hint of such a comprehensive time measurement has emerged from a consideration of the general chemical changes during the life history (Needham, *Nature*, 1932, vol. 130; Waddington, *Nature*, 1933, vol. 131).

After having very clearly, though at great length, developed the concept of physiological time in connection with his two selected processes, Lecomte du Noiÿ attempts to correlate his physiological time with the introspective awareness of the passage of time. He quotes the evidence that awareness of the passage of time is modified by temperature changes and may therefore depend on recurrent physico-chemical processes, but he has not attempted to determine a time unit in terms of recurrences such as the heart-beat, and a direct equating of the apparent relative rates of the passage of time with the rates of cicatrization at various ages results in some rather unconvincing curve-fitting. The subject, however, is clearly one of great difficulty and at the same time of great interest and Lecomte du Noiÿ's little book will be most valuable if it brings the subject to the notice of a larger number of biologists.

C. H. W.

The Student's Manual of Microscopic Technique : With Instructions for Photomicrography. By J. CARROLL TORIAS. [Pp. xviii + 210, with 79 figures.] (London : Chapman & Hall, Ltd., 1936. 10s. 6d. net.)

THE greater part of this book is devoted to a description of the methods of preservation and preparation of material for examination with the microscope. The subject is dealt with in a clear concise manner, which should enable the beginner who follows it carefully to prepare satisfactory slides of almost any material.

The author is a little unfortunate in his choice of relevant subjects. It is somewhat surprising to find the student advised to control intensity of illumination with the diaphragm, especially after a treatment on resolution and numerical aperture, nor is the tilting of the mirror to attain the same end a practice to be recommended.

Some of the methods of distinguishing between diatoms and desmids are unusual; to quote one criterion: "Thus an object that may seem to be either a diatom or a desmid is not a diatom if it moves slowly, nor is it a desmid if it darts around the field like a humming bird": nor, one may add, is it a diatom if it adopts the latter tactics. Again, in reference to *Volvox*, the cœnobium is referred to as the "parent cell," while the "sporific inclusions" are, presumably, daughter cœnobia. Later there is an illustration of "Embryonic seeds in the ovary of Hyacinth," while in reference to beetles, "the thorax is extended to form the prothorax, which carries two pairs of legs, while the thorax carries the anterior pair." Such statements, and there are others of a like nature, seriously detract from the value of the work as a student's manual.

F. W. J.

MEDICINE

The Principles of Bacteriology and Immunity. By W. W. C. TOPLEY M.D., F.R.S., and G. S. WILSON, M.D., D.P.H. Second edition. [Pp. xvi + 1645, with 276 figures.] (London: Edward Arnold & Co., 1936. 50s. net.)

THIS book was first published in 1929 and it has since held a deservedly popular place among the few text-books available for serious students who really want to know about the medical and hygienic aspects of bacteriology and who attend such a course as is given by the authors at the London School of Hygiene where they are the professors of bacteriology. It is divided into four parts: (1) general bacteriology (242 pages), (2) systematic bacteriology (518 pages), (3) infection and resistance (228 pages), and (4) the applications of bacteriology to medicine and hygiene (614 pages). Part 2 is excellent and gives a full account of the pathogenic organisms with slighter notices of some of the others which are of particular interest. Part 4 is also very good and contains a vast amount of learned and interesting information, though the section on virus diseases associated with tumour formation is so flimsy that it might well have been left out altogether: perhaps, however, we ought not to complain if symptoms of exhaustion begin to appear on p. 1537. Part 1 is less satisfying, and intending readers should be warned that they will find such matters as the nutrition of bacteria in general and their relation to temperature treated in a cursory sort of way. The authors insist throughout that bacteriology is an applied science, and it should be understood that the contents of the book are qualified by their outlook and that medicine and hygiene are their objectives. Part 3 is also unsatisfactory, and for some reason the chapter on the combination between antigen and antibody is included in Part 1. It is difficult for anyone who knows something about a subject to be sure how any account of it will appeal to a blank mind, but I cannot help thinking that a raw student who tackles this section will soon be out of his depth and will doubtfully come to the top again. Some of the collocations of facts which are at present the elementary working truths about immunology are nowhere really clearly stated, and the authors must surely be assuming that their readers have some preparatory knowledge. Thus there is no exposition of the evidence for the theorem that antigens are in general proteins from another species of organism: the authors plunge straight into the proof (if proof it is) that there are exceptions to the rule. We are disappointed, too, in finding no adequate discussion of the possibility of selecting races of bacteria and races of hosts either by extraneous means or by their interaction with one another, subjects of considerable practical importance as well as theoretical interest. As a corollary, we notice that the portrait of Charles Darwin which adorned the first edition has disappeared, but we do not believe that applied bacteriology is any the worse for being treated as far as may be on a biological basis. But, with the proviso that it deals with particulars rather than "principles" and that it is suited only to advanced students of a limited aspect of bacteriology, it is a good book and the criticisms we have made show only that it reflects the personalities and interests of the authors as all real books should do. From the reader's point of view I deplore the merging of the two volumes of the first edition into one; the result is monstrously heavy and inconvenient. It would be better to have a rather smaller page and three volumes containing parts 1 and 3, part 2 and part 4: with the present tome the spirit is likely

to be subject to the flesh. The cross-references, which are abundant, should be given to pages instead of chapters which, not being printed in the page headings, are hard to find.

A. E. B.

Bones : A Study of the Development and Structure of the Vertebrate Skeleton. By P. D. F. MURRAY, M.A., D.Sc. [Pp. ix + 203, with 45 figures, including 8 plates.] (Cambridge : at the University Press, 1936. 8s. 6d. net.)

THIS book is a clearly written critical survey of the present state of knowledge of the underlying principles that govern the development and structure of the vertebrate skeleton and is confined mainly to a consideration of the limb skeleton.

The author in his first chapter discusses the factors responsible for the origin and growth of the axial skeleton in the limb bud, and concludes from experimental evidence that the formation and general characters of the pre-natal limb skeleton are due to internal factors inherent in part of the still undifferentiated mesenchyme of the bud and that external factors are of little, if of any, account.

The replacement of the original cartilaginous model by bone (Chapter II) is at first based on the form and structure of the pre-existing cartilage ; only when marked activity sets in after birth do external factors come predominantly into play and form the chief agents in moulding the form and architecture of the bone characteristic of the adult.

Consideration of the development of the normal structure of the skeleton leads (Chapter III) to a discussion of the functional changes in the form of bones induced by the application of special external factors. Such, for example, as torsion due to special muscle traction, flattening due to constant muscle pressure, increase in bulk after removal of one of the bones of the forearm, extensive deformation of the whole limb skeleton after dislocation of the carpus.

The fourth chapter discusses the various theories that have been put forward to account for the internal architecture of the adult long bones. The old " trajectory " theory by which the bone trabeculae are supposed to represent materialised lines of force, though probably true up to a point, is shown by recent observations to be inadequate ; at present no wholly satisfactory explanation is forthcoming.

These four chapters, which form the main substance of the book, are followed by an account of the architecture and physical properties of cartilage (Chapter V) and by a discussion of the possible nature of the factors that initiate osteogenesis and control the deposition and absorption of bone (Chapter VI).

This brief summary can only give an indication of the scope of this excellent and useful little book ; the chief value of the book depends on the full critical analysis of the researches upon which present knowledge of bone growth is based.

R. H. BURNE.

Absorption from the Intestine. By F. VERZÁR, assisted by E. J. McDOUGALL, Ph.D. Monographs on Physiology. [Pp. xii + 294, with 70 figures, including 6 black and white and 6 coloured plates.] (London, New York, Toronto: Longmans, Green & Co., 1936. 21s. net.)

THIS book is a worthy and welcome addition to the series of monographs on Physiology now edited by Prof. Lovatt Evans. Absorption as a subject of research attracted very little attention from the close of the last century until a revival of interest set in about ten years ago; but in spite of many recent advances and of the scientific and practical importance of the subject it is still far from popular. The book has accordingly appeared at a particularly opportune time thanks to the editor of the series as well as to the author.

Prof. Verzář is one of the most energetic investigators in this field and his enthusiasm has inspired bands of younger colleagues in the Universities of Basle and Debreczen with whose assistance he has made many important contributions to the subject, especially concerning the absorption of carbohydrates and fats and the rôle of the intestinal villi. While it would be untrue to say that the author has not made a very impartial appraisal of the work of others, it is only to be expected that his conceptions should be dominated by the numerous researches he has conducted or inspired. His several interesting conclusions bear the imprint of clear thinking and careful experimentation, and, although they carry conviction on the whole, one has the feeling that the phenomena of absorption may be more complicated than his syntheses indicate. His conclusions that the pumping of the villi is an important factor in fat absorption and that combination of phosphate with glucose, galactose and fatty acid (phosphorylation, which depends on the adrenal cortical hormone) in the intestinal mucosa plays an essential part in the absorption of carbohydrates and fats are supported by much evidence from many sources. But his contention that glucose is absorbed at a constant rate, irrespective of concentration, does not appear to conform to all the facts.

The old controversy about the form in which fats are absorbed would seem to be settled, mainly by Verzář's work, more in favour of Pflüger than his opponents, and there can be little doubt that the passage of the fatty acids into the epithelium depends on the hydrotropic action of the bile acids. The establishment of this fact is a very important addition to general physiology and the principle has probably many other biological applications. A section on the pathology of fat absorption will appeal to clinicians, and the excellent chapters on the anatomy of the intestines and on methods of research will be appreciated by students of the subject. The difficult problems involved in the absorption of water have been adequately dealt with, but the two chapters on the inorganic elements, especially the section on iron, are incomplete.

The previously intensive research on absorption fizzled out at the beginning of the century in a number of futile polemical papers on the respective merits of the mechanistic and vitalistic conceptions of the process. Verzář has attempted to revive the controversy by arguing against vital forces. However, his views do not seem to harmonise completely with those of the older thorough-going mechanists; for, in rightly insisting on the necessity of experiments on intact animals for establishing facts of physiological significance, he testifies to his belief in the existence of forces in living animals

which are not present in isolated tissues, much less in dead animals. It seems to the reviewer that discussions on matters of this sort are more appropriate to a work on philosophy than to one on experimental science.

The book is well produced, adequately illustrated and concisely and clearly written, notwithstanding frequent lapses into phraseology of a German flavour. To appraise the literature, about 1,300 papers, and to record the trend of recent researches on the subject within the space of 257 pages is an achievement for which the author and his assistant author (Dr. McDougall) are to be congratulated.

H. E. M.

Food and the Principles of Dietetics. By ROBERT HUTCHISON, M.D., LL.D., F.R.C.P., and V. H. MOTTRAM, M.A. Eighth edition. [Pp. xxviii + 634, with 32 figures.] (London: Edward Arnold & Co., 1936. 21s. net.)

FREQUENT demand for new editions and reprints testifies to the high esteem in which this book has been held. As first conceived thirty years ago, Dr. Robert Hutchison's text-book was a pioneer effort to ally the young science of nutrition with practical dietetics, a branch of medicine much neglected. In later editions Prof. V. H. Mottram collaborated. An added feature in the eighth edition is a survey of the history of dietetics showing that this subject was a jumble of absurd beliefs and fallacies until it was put on a scientific basis. Rather astonishing is the authors' omission to do homage to Dr. James Lind, Dr. William Cadogan, Sir Gilbert Blane and other shrewd men, who in the eighteenth century had a foresight in nutritional matters far in advance of their time.

In the last century the labours of physiologists modified the theory and practice of dietetics, particularly in relation to the quantity of food required as expressed in terms of energy value. In the twentieth century, discovery of vitamins and urgent need to solve difficulties in feeding armies and civilian populations in war and in slump abnormally accelerated research in nutrition and shifted the focus of interest to the qualitative nature of foodstuffs.

There is now an accumulation of scientific data, and their application in the nutritional problems of daily life is hindered by affectionate clinging to old habits and traditions—a tendency visible in this timeworn book. It is doubtful if a text-book on dietetics dating from 1900 could by any process of revision be made valid to-day. This book no longer lives. It is a patchwork of old and new materials which lack cohesion. By omissions here and over-emphasis there, a distorted perspective is created. There is no proper sense of proportion. Three chapters (57 pages in all) are devoted to alcoholic beverages; 25 pages to tea, coffee and cocoa; 19 to soups and meat extracts; 13 to mineral waters; while the intricate subject of vitamins is segregated within a small sub-section of less than 11 pages. The authors still refer to vitamins as *elusive*, although their chemical constitution is known and they are measurable by standards of International Units. We find no tables of vitamin values, either in terms of units or in weights of common foodstuffs. No figures are given for man's daily vitamin requirements in those cases in which they can now be estimated. Vaguely and with misleading optimism the authors assume that the average diet contains enough vitamin B₁ and ridicule as *faddists* those who stress the need for a calculated supply as opposed to guesswork.

It is with relief that we turn to the long-established facts of the section on digestion. A perusal of this may re-assure those who have recently lost faith in the kindly Providence that decreed protein and starch should occur together in many natural foodstuffs and endowed us with digestive organs designed to deal with the mixture. May they be encouraged to laugh at the American craze which would deny us bread with cheese, or toast with egg, strip the pie crust from steak and kidney, and rob roast beef of Yorkshire pudding.

R. H. A. P.

Nutritional Factors in Disease. By W. R. FEARON, M.B., Sc.D., F.I.C. Monographs of Medical and Surgical Science. [Pp. xiv + 141.] (London: William Heinemann (Medical Books) Ltd., 1936. 7s. 6d. net.)

THIS essay now published in book form was awarded the Buckston-Brown prize for 1935 by the Harveian Society of London. Perhaps an equally apt title would be "Nutrition and Health." It is an account of the balancing of two opposing activities, one intrinsic in tissues and organs making for depletion and the other the activity of the organism making for nutritional enrichment. In effect this essay is a concentrated digest of the present-day knowledge of biochemistry applied to the human body. To include in about 120 pages a résumé of this wide and important subject, involving a bibliography of 268 references, has meant a degree of compression approaching a catalogue nature, which does not go with easy reading.

Five chief sections are considered: (1) The nature of nutrition including foodstuffs and dietary standards; (2) The nutritional factors of health and disease including the action of Carbohydrates, Proteins, Lipids; (3) Inorganic foodstuffs, water and alkali metals; (4) the inorganic micro-constituents of food, iron, copper, iodine, etc.; (5) organic micro constituents, Vitamins. Each part is full of great interest, but it is difficult to say to what class of reader the book will appeal. For the average medical practitioner it is too specialised except as a book of reference; for the biochemist it is too generalised; to the medical officer of health and especially to the medically trained social worker it should perhaps be a helpful guide.

P. J.

The Improvement of Sight by Natural Methods. By C. S. PRICE, M.B.E. Second edition. [Pp. xii + 240, with 30 figures.] (London: Chapman & Hall, Ltd., 1936. 5s. net.)

THE fact that this book has reached a second edition after two years indicates that it has made a wide appeal, and, in so far as this indicates a healthy reaction (which should not be pushed to extremes) against the indiscriminate ordering of glasses, this is all to the good. With some of the subject-matter not all would agree, but there is food for thought in many of its pages.

This edition is enlarged by some seven pages, and includes several new diagrams. One minor point, which might well be altered in any subsequent edition, is the author's assessment of the value of treatment of detached retina, which is based on out-of-date knowledge. Modern operative measures now give 40 per cent. or even 50 per cent. of cures in recent cases, which entirely alters the outlook in this affection.

M. L. H.

Laboratory Experiments in Physiological Chemistry. By A. K. ANDERSON, Ph.D. [Pp. vi + 224 with 20 figures.] (New York : John Wiley & Sons, Inc. ; London : Chapman & Hall, Ltd., 1936. 7s. 6d. net.)

IN spite of its relatively recent development, the science of Biochemistry has already proved itself to be of great importance in many different branches of study, and in numerous fields of practical activity. About a year ago Prof. Anderson published a text-book primarily intended for students of hygiene and nutrition. The present volume provides a short laboratory course—intended to last one term of about six hours per week—for the same type of student. It is assumed that the worker has had practically no previous knowledge of chemical methods. Thus the course begins with practice in the use of the balance, and in the methods of volumetric analysis. Obviously, such a course is not an easy one to draw up, for, in the effort to make it sufficiently inclusive, there is a very real risk of giving the appearance of superficiality. Many readers will probably conclude that Prof. Anderson has not been altogether successful in avoiding this difficulty. A feature of the book is the inclusion, at the end of each section, of a number of questions—most of them very simple ones—on the experiments which the student will have just carried out, and on the theoretical issues involved. Over the greater part of the book the alternate pages have been left blank. This is doubtless a convenient device, but it is perhaps appropriate in a review to remark on one incidental result. As the blank pages are included in the page numbering, the actual number of printed pages is 128 and not 224 as might be inferred from the heading above.

W. O. K.

PHILOSOPHY AND HISTORY OF SCIENCE

Growth of the Mind in Relation to Culture. By C. LAMBEK. Translated from the Danish by AGNETE KORTSEN. [Pp. 143.] (Copenhagen : Levin & Munksgaard ; London : Williams & Norgate, Ltd., 1936. Kr.6.50.)

THE *Growth of the Mind in Relation to Culture* constitutes an attempt to evaluate the cultural interests of human life from the point of view of an idealistic philosophy. It might, not inappropriately perhaps, be described as a programme of progress, built up upon the lowest, and most material, basis of bodily comfort, ease and security of living, increased self-confidence and similar benefits that our forefathers understood, judged to be worth while, and incorporated into their earliest appreciated values of riches, power and glory. Because in many ways, and for most people and governments, the idea of culture still remains attached to these primitive values which, while they may form a foundation for its support, do not of themselves make for progress, the purpose of the essay is to show that advance in culture is only possible through liberation and cultivation of the mind, and that this can only be secured by vitalisation, mental activity and coherence, independence, and the working out of a reliable life order. "The sole aim of culture must . . . be to provide conditions which will in future give greater value to conscious life." This doctrine, as developed in the *Growth of the Mind*, is an indictment of materialism as a social, moral and cultural principle ; and the indictment is vigorously pressed home in the last Chapter of the book

on "Man of To-day", in which a most pessimistic picture is presented of the scepticism, insecurity and superficiality of contemporary society. For the ordinary man to-day "the great pulsing world, of which he has picked up a number of hasty glimpses, is . . . only a chaotic mass without order or meaning. In this chaos his own personality is lost. There is no room for the development of his own inner life." What is the remedy suggested for so deplorable a state of affairs? The cultivation of the one thing needful, upon which all values depend: inner dynamic coherence in mental life. "On the day when our descendants can hand down to their children an understanding of life, which is equal to the knowledge we now possess of the dynamics of the material world--on that day the tragedy of culture on this earth will be over." There are many misprints in this book (it was printed in Denmark) and some incorrectly rendered words. It also lacks an Index.

F. A.

Biology and the New Physics: A Plea for a Consistent Philosophy of Life. By C. J. BOND, C.M.G., F.R.C.S., F.L.S. [Pp. 67.] (London: H. K. Lewis & Co., Ltd., 1936. Cloth, 2s. 6d. net; paper covers, 1s. 6d. net.)

THE author in a short book wishes to draw the attention of the public to the need for a revaluation and a reconsideration of the position of biology in the light of the new concepts introduced by modern physics and in particular the "uncertainty principle." As he very rightly remarks in his introduction, "civilised man is to-day being called upon to exercise increasing control over human evolution, and he must be equipped with scientific knowledge, and a sound Philosophy of Life if he is to carry out this great task successfully." He does not claim to give such a revaluation in so short a space, but merely to indicate how it might be done. Two of the seven chapters are devoted to statements on the new physics, and the remainder of the book to biological considerations. It cannot be said that he succeeds to any marked extent. He quotes from many sources and shows that there is considerable disagreement among the authorities concerning the implications of their work. He does not state precisely and unequivocally which he believes to be valid and why, nor does he provide clear alternatives.

Mr. Bond has read very widely, but he is apparently unaware of the quite extensive contributions to this subject that are being made by the school of philosophy known as "Dialectical Materialism." It may be argued that the size of his book precluded such an examination, but it could have been done at the expense of some of the other less relevant considerations.

C. G.

Prelude to Chemistry: An Outline of Alchemy, its Literature and Relationships. By J. READ, Ph.D., M.A., Sc.D., F.R.S. [Pp. xxiv + 328, with 64 plates and 17 figures.] (London: G. Bell & Sons, Ltd., 1936. 12s. 6d. net.)

PROF. READ has put together a series of chapters on the history and meaning of alchemy which are equally fascinating and scholarly. From the beginnings in China and Egypt, he traces the progress of alchemy through the Saracen centres of learning to its appearance in Europe in the twelfth century, and its further development until the seventeenth century. A description of its strange doctrines and its curious literature, a glance at the lives and person-

alities of its devotees, and a sympathetic attempt to elucidate the inner meaning of some of its mysteries, all make up a study of alchemy which can be read with keen interest both by the specialist and by the ordinary reader without detailed knowledge of Chemistry. There are excellent bibliographies, and the illustrations, over a hundred in number and including a splendid coloured frontispiece, add to the value and attractiveness of the book. As the cover of the book announces, the reader is led through exhibits of mythology, magic, astrology, gold-making, music, art and romance. If he can find nothing of interest in these he must be dull indeed.

J. R. P.

Historical Introduction to Chemistry. By T. M. LOWRY, C.B.E., M.A., D.Sc., F.R.S. [Pp. xv + 581, with 57 figures.] (London: Macmillan & Co., Ltd., 1936. 10s. 6d. net.)

THE late Prof. Lowry's valuable historical work, now in its third impression twenty-one years after its first appearance, continues to serve that useful purpose for which it was originally written, namely, "to present an historical account of the more important facts and theories of chemistry, as these disclosed themselves to the original workers in this branch of science," with which end in view "no attempt has been made to write a formal History of Chemistry." Its accurate and detailed references to the original literature of chemistry continue to be a most valuable feature of the book. In this reimpression opportunity has been taken to make some slight changes in the text, but a more important change has been made in the chapter on "The Classification of the Elements" by the inclusion of Mendeleëff's Periodic Table as published in Liebig's *Annalen* in 1871.

In the "Biographical Index," the entry on p. 556 under "Macquer" should read "116"; the date of Monge's experiments (p. 557) should read "1783"; and the last entry on p. 559 under "Priestley" for the year 1776 should read "166."

D. McKIE.

MISCELLANEOUS

Glamorgan County History. Vol. I: Natural History. Edited by Prof. W. M. TATTERSALL. [Pp. xx + 444, with 40 plates, 27 figures and 4 maps.] (Cardiff: William Lewis (Printers), Ltd., for the Committee, 1936. 25s. net.)

UNDER the Editorial board elected in 1931 a scheme for a Glamorgan History in six volumes was projected, of which the present work is the first fruits, and it is no mere formality to say that the committee are to be congratulated upon the result produced, with the help of over 180 subscribers, at a price so moderate, having regard to the size of the volume and its excellent production.

After a general survey of the topography of the area by Prof. Trueman, the same author, in collaboration with Prof. Fox, gives an account of the interesting geological history of the area, which is continued by Dr. North. The great earth movements which occurred in late Carboniferous times determined the main structure of the Devonian carboniferous rocks that are most prominent at the surface of the county to-day. Earth movements too have produced the interesting pre-glacial raised beaches of the Gower Peninsula, and this rise of land in respect to the sea produced coastal plains

bearing oak-hazel forests that, owing to subsequent post-glacial changes of level, gave rise to the submerged forest of the Bristol Channel. Those changes in level and the various phenomena of erosion and accretion furnish a useful introduction for the subsequent matter.

Mr. S. W. Ryder treats of the meteorological conditions, which show a wide range of rainfall from 35 inches in the coastal area to over 90 inches in the hills, seasonally distributed, with April, May and June as the driest months, throughout the area. Prof. Robinson and Mr. Hughes follow with a description of the soils, of a rather technical character that will leave the reader with many questions unanswered. The flowering plants of the area are described by Miss Vachell; they include a large number of interesting species amongst which we may mention *Sorbus porrigens*, *Draba aizoides* v. *maritima*, *Aconitum anglicum*, *Cirsium tuberosum* and *Rumex rupestris*. A list of the mosses and hepatics is given by Mr. Knight and includes several rare species. Mr. Wade and Dr. Watson give a list of 324 species of Lichens, and Mr. Kenneth Rees furnishes a list of marine algae.

Amongst the fresh water algae of Glamorgan listed by Mr. Harris a particularly interesting occurrence is that of *Cyclonexis annularis*, a member of the Chrysophyceae, which has hitherto only been recorded on a single occasion from Germany, North America and Lapworth in Warwickshire.

The Higher Fungi are dealt with by Miss Wakefield, the Phycomycetes by Dr. Iviney-Cook, and Mycetoza by Miss Lister. There follow accounts of the trees and shrubs by Mr. Hyde, of crop plants and their diseases by Mr. Rees and notes on the ecology of the vegetation by Prof. MacLean.

The Zoological section occupies rather less than half the book and is contributed by Colin Matheson, Messrs. Ingram and Salmon (Ornithology); Reptiles and Amphibians are dealt with by Mr. Loveridge; Fishes by Mr. Salmon; The Insects by Mr. Hallett and Mr. Thompson; The Arachnida, numbering 191 species, by Mr. Jackson; and the non-marine mollusca, treated on a habitat basis, by Mr. Dean. Mr. Thompson adds an account of the lymnæidæ affected by parasitic trematodes, and Mr. Harris deals with the Rotifers.

It need scarcely be said that with such a diversity of voluntary contributors the treatment is somewhat unequal and varied in its approach. This has certain advantages but here carries with it the defect that the contributions bear little relation to one another. Taken as a whole, the work is a notable contribution to the Natural History of Local Areas and it is to be hoped that later volumes will maintain the standard set by Prof. Tattersall.

E. J. S.

Scientific Progress. Sir Halley Stewart Lectures, 1935. [Pp. 210, with 31 figures, including 4 plates.] (London: George Allen & Unwin, Ltd., 1936. 7s. 6d. net.)

SIR JAMES JEANS starts off these lectures with an essay on *Man and the Universe* in which he returns to his thesis that the fundamental questions can only be answered by the mathematician, and asserts his belief that Eddington's calculations concerning the ratio of the masses of the proton and electron are correct to as many decimal points as we please. Sir William Bragg follows with a fascinating account of *The Progress of Physical Science* in which he is chiefly concerned with the advance in knowledge of atomic structure. *The Electricity in the Atmosphere* is the subject taken by Prof.

E. V. Appleton and of several interesting problems discussed is that of the earth's negative charge. He favours Wilson's theory that the thunderstorms in the Dutch East Indies, South Africa and South America are chiefly responsible for providing the thousand amperes necessary for maintaining the surface charge.

Advances in medicine are described in a very interesting lecture illustrated by statistical graphs entitled *Progress in Medical Science*, by Prof. Mellanby. Prof. J. B. S. Haldane disposes of many popular misconceptions with regard to heredity in *Human Genetics and Human Ideals*. Prof. Julian Huxley concludes these lectures with a defence of science entitled *Science and its Relation to Social Needs*.

G. B. BROWN.

Stone Age Africa: an Outline of Prehistory in Africa. By L. S. B. LEAKEY. [Pp. xii + 218, with 14 plates, 2 folding plates and 28 figures.] (London: Oxford University Press, 1936. 7s. 6d. net.)

DR. LEAKEY'S book—an expanded version of his Munro Lectures for 1935–36—is a valuable and timely survey of present knowledge of the Stone Age in Africa. To appreciate its merits to the full and to gauge recent progress, the student would do well to glance once again through Mr. M. C. Burkitt's *South Africa in Stone and Paint*.

The subject bristles with difficulties. This arises in part from the fact that research in African archaeology has been very much departmentalised and correlations at present are by no means easy to determine. Thanks to the researches in Uganda of Mr. E. J. Wayland and of Dr. Leakey himself in Kenya, it is becoming increasingly evident that the position of East Africa is pivotal; but both in South and North Africa recent advances in working out the chronological and typological relations of local cultures hold out definite promise of a clearing up of doubtful points at no distant date. When this time comes, North Africa, in dealing with which area Dr. Leakey does full justice to the recent work of M. Vaufrey, will hold a position of possibly even greater importance in view of its relation to Europe, and it may be Palestine, where Miss Garrod's recent late palæolithic and mesolithic discoveries throw a new light on early cultural movement. The position of Africa, in the early development of culture and also of man, is one of the most interesting of the numerous problems with which Dr. Leakey deals.

In addition to his chapters on the archaeology of East, South, North and West Africa, the author devotes one chapter to African Stone Age art and one to Stone Age man, in which the evidence for Early man in Kenya is fully discussed.

E. N. F.

The Emergence of Human Culture. By CARL J. WARDEN. [Pp. x + 189, with 10 figures, including 3 plates.] (New York and London: Macmillan & Co., Ltd., 1936. 8s. 6d. net.)

At what point in organic evolution can it be said that man becomes man, and by what criterion is the line of demarcation between the animal and the specifically human to be determined? Until the common ancestor of man and the ape is found, if indeed that much-desired discovery is ever made, and until prehistoric studies take us back a great many stages farther

than they are able to do at present, the answer to these questions must depend in no small degree upon the basis of classification and definition. Dr. Warden's solution of the problem is that the character which differentiates man as such is culture; but he goes on to point out that, not only is man as a self-domesticating animal the author of culture, he is also its product. Startling statement as this may seem at first sight, it requires only a little reflection to appreciate its truth, even when applied to man in the most rudimentary forms of human society. For even before birth and throughout the whole formative period of his existence man, physiologically and psychologically, is being moulded by the cultural pattern of the community into which he was born. Taking culture, then, as his criterion, Dr. Warden proceeds to show how, when applied to the scheme of organic evolution, cultural development not only serves as a measure of man's progress from primitive to civilised, but also, when contrasted with the sociobiological stage, such as is manifested in the behaviour of ants and bees and certain practices of monkeys and anthropoid apes, it draws the line between the instinctive and inherited, and the rational and human, which must be implanted by education and training.

E. N. F.

The Law and the Prophets. By HAROLD PEAKE and H. J. FLEURE. [Pp. viii + 188, with 52 figures.] (Oxford: at the Clarendon Press; London: Humphrey Milford, 1936. 5s. net.)

THIS volume is No. IX in the series "The Corridors of Time," in which the authors have set out to sketch the evolution of human society during pre-historic time. Here they are concerned with the period which experienced the full effects of the adoption of iron as a principal tool material, and the accompanying clashes of cultures and peoples in all the civilised lands of the Old World. The clash of ideas led to fresh consideration of fundamental problems in the relations and duties of the individual to the social group, and vice versa. The authors give a concise outline of the resulting developments in the ideals and achievements of Hebrew prophets and Hellenic statesmen, of Hindu and Buddhist philosophers, and of the sages of China and the lawgivers of Rome, all of them reacting to the new conditions and possibilities.

The authors see value in both of the two hypotheses of diffusion of culture and of parallel evolution of culture in different lands under similar circumstances, and hold that in many cases both sets of factors may have been present. Their conclusions are supported by a wealth of detailed evidence. The amount of detail is indeed such that there is sometimes a danger that the non-specialist reader, for whom the books are apparently intended, may fail to see the wood for the trees. But the work is well worth the careful reading it demands. Like the rest of the series it is a great achievement in the presentation of the results of a vast amount of work in a moderate compass.

C. B. F.

A History of Europe. By the RT. HON. H. A. L. FISHER, P.C., D.C.L., F.B.A., F.R.S. [Pp. xiv + 1301, with 34 maps.] (London: Edward Arnold & Co., 1936. 10s. 6d. net.)

A BOOK of 1300 pages at the modest price of 10s. 6d. is something of a publishing *tour de force*—especially in the case of a book which, on the face of

it, would seem to have an "academic," rather than a "popular," appeal. How, one may wonder, has it been done? One need not wonder long; one has to read but a few pages to discover the method underlying the publishers' illusory insanity. That a *History of Europe* written by the Warden of New College must be a good history would be merely a reasonable assumption. A good history, however, may be far removed from a great history; and the history which Mr. Fisher actually has written belongs unquestionably to the small and select company of really great histories. As such, it will surely gain a monopoly in its own particular field; and even when, in years to come, that monopoly passes to some newer history, scholars and students still will turn to it as the classic humanist interpretation of European progress.

An elder Liberal statesman in whom Liberal doctrines are deeply engrained, Mr. Fisher frankly views the world through Liberal eyes, but it would be absurd to reproach him for this; he is much too sound a scholar to seek to serve any narrow party end, and his critical examination of what he calls "the Liberal experiment" of the nineteenth century is nothing short of an astonishing achievement of penetrating thought. Many of us at the moment are dismayed by the apparent failure of that Liberal experiment. But has it failed? "The tides of liberty have now suddenly receded over wide tracts of Europe," writes Mr. Fisher, and, no doubt, his metaphor was chosen with deliberate care; when the tide turns, it well may be that Stalin, Mussolini and Hitler alike will be as impotent as was Canute to stay an incoming flood. Europe, Mr. Fisher concludes, "has now reached a point at which . . . two alternative and sharply contrasted destinies await her. She may travel down the road to a new war or, overcoming passion, prejudice and hysteria, work for a permanent organisation of peace. In either case the human spirit is armed with material power. The developing miracle of science is at our disposal to use or abuse, to make or to mar. With science we may lay civilisation in ruins or enter into a period of plenty and well-being the like of which has never been experienced by mankind."

J. A. B.

Principles and Laws of Sociology. By HAROLD A. PHELPS. Wiley Social Science Series. [Pp. xiv + 544.] (New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd., 1936. 20s. net.)

THIS useful work by the Professor of Sociology at the University of Pittsburgh is a survey of what sociologists have considered to be statements of law and principle. It begins accordingly with a discussion on the scope and nature of Sociology. The second part of the book considers the sweeping laws and generalisations which characterised early Sociology. In the third part the much more limited laws and principles of recent social thought are analysed. And in the fourth and final part such topics as social trends, social prediction and symbolic Sociology are examined and it is argued that "the specific requirements of a Sociology with a valid body of laws are (1) clearly defined units and variables, (2) susceptibility to verification, (3) adequate samples, (4) clearly defined limits, (5) predictability or applicability to comparable situations and (6) usefulness in social control."

If we compare present-day Sociology with that of the nineteenth century one clear "trend" definitely emerges. In place of the grandiose schemes, laws and single-factor explanations (e.g. Comte's Law of Three Stages, Tarde's Law of Imitation) present emphasis is on strictly limited, precise and as far

as possible quantitative laws (*e.g.* Pearl's logistic law of population, Engel's law "that the greater the income of a family, the smaller the percentage outlay for food"). A social law is now "simply a statement of probable events and sequences not of their invariable certainty or of their efficiency as explanations of causes." Research into "society" in general has given way to the intensive study of social segments, of subordinate social structures, of limited social patterns such as population or urbanisation.

The results of such intensive study are given in the third and most important part of the book, where a detailed examination is made of the laws applicable to the social patterns of population, urbanisation, ruralisation, industrialisation, mobility, social organisation and social class. The results, however, are rather disappointing. Although the author rightly stresses the value of precise empirical quantitative and qualitative laws (*e.g.* those of Gompertz, Pearl, Fairchild with regard to population) it should not be forgotten that their subsumption under wider laws and their interpretation in the light of the more ultimate laws of life and mind must also be attempted by a scientific Sociology. Herein lies the significance of the "cosmic" generalisations of the early sociologists. Nor should it be forgotten that precise quantitative laws to which the author is so partial are not necessarily valid. The form of a law is no guarantee of its validity. Pearl's logistic law is not applicable to human populations. Engel's law does not hold for the larger part of the world's inhabitants.

The utility of this book would have been greatly enhanced had the author examined critically the whole problem of social causation. If science is a study of causes, a law that is no more than "a statement of probable events and sequences and not of their invariable certainty or of their efficiency as explanations of causes" does not yield much information. But science is more than a study of causes for it also attempts to arrange the causes in a hierarchy of significance. We must know what factors are most important in any social pattern and what framework of categories we must devise to guide us through their labyrinthine complexity to the discovery of social laws. And we must also remember that social laws only have relevance in specific historical configurations. Social laws (*e.g.* those of Engels, Ricardo, Malthus), are not eternal laws of nature. They are historic laws which arise and disappear.

J. RUMNEY.

Soviet Science. By J. G. CROWTHER. [Pp. x + 342, with 16 plates.] (London: Kegan Paul, Trench, Trubner & Co., Ltd., 1936. 12s. 6d. net.)

THE writer of this book has paid seven visits to Russia in recent years and has been the guest of the Scientific Section of the Department of Heavy Industry. He is therefore able to describe scientific developments in a country which spends a far greater proportion of its national wealth on science than any other. These developments are said to be incomprehensible without some knowledge of the philosophy of Dialectical Materialism. Fortunately this is not so, otherwise they would remain incomprehensible in spite of a chapter devoted to elucidation of this meaningless hotch-potch of misunderstood science and class hatred. Needless to say, science progresses in the U.S.S.R. by the use of the Baconian method in imitation of the Western world, and is not conditioned by the "contradiction of opposites," modes

of production, the class struggle, or any other Hegelo-Marxian catch-phrase. Everything is, of course, planned, and the scientist is not allowed to give "harmful expression to illusory ideas of absolute freedom, or behave with social irresponsibility." In researching into the history of science full scope is given for the dialectical materialist approach; Newton's *Principia* is found to have economic and social roots, and the exaltation of theory over experiment (very noticeable in present-day physics!) is due to the fact that science is pursued by the leisured classes who dislike manual work. All this will strike the English reader as very childish, and almost as pathetic as Nazi racialism. Nevertheless, there is a great deal going on, and the book gives an excellent survey of it. Presumably something will come of all this planning, but at present the best conclusion seems to be to use metaphorically a statement of the author's concerning the rooms in Leningrad in which scientists from the provinces are accommodated: "In spite of the strict management, the rooms are not entirely free from vermin."

G. B. BROWN.

Science fights Death. By D. STARK MURRAY, B.Sc., M.B., Ch.B.
Changing World Library, No. 4. [Pp. x + 149, with 18 figures.]
(London: C. A. Watts & Co., Ltd., 1936. 2s. 6d. net.)

IN the early days the duty of medicine was to cure disease. When the nineteenth century science arrived it taught that medical science should prevent disease, and from this there followed the modern "Production of Health." But this involves the service not only of medical science but the co-operation of a more and more enlightened body of lay workers, the patients of yesterday. Most of these are in a state of aboriginal ignorance concerning the simplest common-place relations of their body structure or of the extent and nature of the many influences which produce disease and injury.

This little book seems to supply a real want. It is full of the most elementary yet essential facts; it should be found in every home and school room.

We find objection in the title; it is pessimistic and foolish for it would seem useless to fight anything that is dead; surely it would be better and more hopeful if "Science fights for Health."

On page 77 the pancreas is referred to as the "sweet bread" of course the true sweet bread is the thymus gland.

P. J.

Statistical Methods for Research Workers. By R. A. FISHER, Sc.D., F.R.S. Sixth edition. Biological Monographs and Manuals, No. V. [Pp. xvi + 339, with 12 figures.] (Edinburgh and London: Oliver & Boyd, 1936. 15s. net.)

THIS new edition of Prof. Fisher's book appears only two years after the publication of the previous edition, thus demonstrating the continued usefulness of this work. The new edition includes 20 or so more pages than the previous edition. The Table of "z" has been extended to include 0.1 per cent. points of the distribution of "z," and various passages have been enlarged slightly. For the greater part the book continues to be its own efficient self.

E. C. RHODES.

Preparation of Scientific and Technical Papers. By SAM F. TRELEASE and EMMA SAREPTA YULE. Third edition. [Pp. 125.] (Baltimore: The Williams & Wilkins Co.; London: Baillière, Tindall & Cox, 1936. 7s. net.)

THIS is a very useful book, and, while individual opinions may differ on various points of detail, there is no doubt that would-be authors of scientific papers or reports, or even books, could read and learn from this volume with advantage.

The authors start by suggesting that, before the writing of a manuscript is begun, a summary of the contents should be made and the probable headings set out. This advice is heartily to be commended, and, from the reviewer's knowledge, many hours of fruitless writing could be saved by authors if they only adopted this plan.

There follows information on the kinds of type that may be used, and the underlining to be adopted to indicate them. Here a word of warning may be given. It is not wise to assume that every printer will have the same convention as to the kinds of type the various underlinings indicate, and it is desirable to mention at the start of a manuscript, under such a heading as "Notes to Printer," what the various underlinings denote.

In dealing with corrections in a manuscript, the authors suggest that these should be made in the body of the manuscript rather than in the margin. On this point there can be two opinions. If there is ample room in the text a correction may be inserted above the line, but it is often far better to indicate the place in the line where the correction comes and insert the same in the margin, where there is more space.

A list of abbreviations is given for weights and measures, etc., but it should be noted that American and British practice are not always the same, e.g. cc and not c.c. is given. The advice on the setting out of plant and animal names should prove very helpful.

The authors then give a method of setting out references to journals, books, pamphlets, etc., and give a list of abbreviations for the more common scientific journals. These abbreviations cannot be recommended. They do not follow those given in the "World List" and do not agree with those adopted in certain of the scientific journals of this country where the abbreviations of the "World List" are not used.

F. P. D.

BOOKS RECEIVED

(Publishers are requested to notify prices.)

- The Theory of Linear Operators.** From the Standpoint of Differential Equations of Infinite Order. By Harold T. Davis, Indiana University and the Cowles Commission for Research in Economics. Monograph of the Waterman Institute of Indiana University, No. 72. Bloomington, Indiana: The Principia Press; London: Williams & Norgate, Ltd., 1936. (Pp. xiv + 628, with 23 figures.) 35s. net.
- Trigonometry. Part I: Intermediate Trigonometry.** By T. M. MacRobert, M.A., D.Sc., Professor of Mathematics in the University of Glasgow, and William Arthur, M.A., Lecturer in Mathematics in the University of Glasgow. London: Methuen & Co., Ltd., 1937. (Pp. xii + 206, with 76 figures and 5 tables.) 5s. 6d.
- Comets.** Their Nature, Origin and Place in the Science of Astronomy. By Mary Proctor, F.R.A.S., and Dr. A. C. D. Crommelin, B.A., F.R.A.S. London: The Technical Press, Ltd., 1937. (Pp. xii + 204, with 3 plates and 6 figures.) 8s. 6d. net.
- Weather Rambles.** By W. J. Humphreys, C.E., Ph.D., Collaborator, U.S. Weather Bureau. London: Baillière, Tindall & Cox, 1937. (Pp. viii + 265, with 37 figures.) 11s. 6d. net.
- The Climates of the Continents.** By W. G. Kendrew, M.A. Third edition. Oxford: at the Clarendon Press; London: Humphrey Milford, 1937. (Pp. xii + 473, with 160 figures.) 21s. net.
- The General Properties of Matter.** By F. H. Newman, D.Sc., A.R.C.S., F.Inst.P., Professor of Physics, and V. H. L. Searle, M.Sc., Lecturer in Physics, University College of the South-West of England, Exeter. Third edition. London: Ernest Benn, Ltd., 1936. (Pp. 427, with 117 figures and 18 tables.) 18s. net.
- Properties of Matter.** By D. N. Shorthose, M.A., Physics Master, the City of Leeds School. London: William Heinemann, Ltd., 1937. (Pp. viii + 150, with 83 figures.) 4s.
- Mechanics, Molecular Physics, Heat, and Sound.** By Robert Andrews Millikan, Director of the Norman Bridge Laboratory of Physics, California Institute of Technology, Duane Roller, Professor of Physics, University of Oklahoma, and Earnest Charles Watson, Professor of Physics, California Institute of Technology. Boston, Mass.: Ginn & Co., 1937. (Pp. xiv + 498, with frontispiece, 54 plates and 268 figures.) \$4.00.
- Concise School Physics. Mechanics.** By R. G. Shackel, M.A., Head of the Physics Department, St. Olave's Grammar School, London. London,

- New York, Toronto : Longmans, Green & Co., 1937. (Pp. viii + 184, with frontispiece and 148 figures.) 2s. 9d.
- An Introduction to Fluid Mechanics. By Alex. H. Jameson, M.Sc., M.Inst.C.E., F.K.C., Emeritus Professor of Civil Engineering, University of London. London, New York, Toronto : Longmans, Green & Co., 1937. (Pp. x + 239, with 116 figures and 8 tables.) 7s. 6d. net.
- Structure and Molecular Forces in (a) Pure Liquids and (b) Solutions. A General Discussion held by the Faraday Society, September 1936. London : Gurney & Jackson, for the Society, 1937. (Pp. 282, with numerous figures and tables.) 12s. 6d. net.
- The Newer Alchemy. Based on the Henry Sidgwick Memorial Lecture delivered at Newnham College, Cambridge, November 1936. By Lord Rutherford, O.M., F.R.S., Cavendish Professor of Experimental Physics in the University of Cambridge. Cambridge : at the University Press, 1937. (Pp. viii + 67, with 13 plates and 8 figures.) 3s. 6d. net.
- Structure of Atomic Nuclei and Nuclear Transformations. By G. Gamow. Being a Second edition of "Constitution of Atomic Nuclei and Radioactivity." The International Series of Monographs on Physics. Oxford : at the Clarendon Press ; London : Humphrey Milford, 1937. (Pp. xii + 270, with 3 plates, 70 figures and 24 tables.) 17s. 6d. net.
- Atomic Spectra and the Vector Model. By A. C. Candler, Sometime Scholar of Trinity College, Cambridge. Vol. I : Series Spectra. Vol. II : Complex Spectra. Cambridge : at the University Press, 1937. (Vol. I : pp. viii + 237, with 4 plates and 142 figures ; Vol. II : pp. vi + 273, with 4 plates and 212 figures.) 15s. net each.
- Electricity and Magnetism. An Introduction to the Mathematical Theory. By A. S. Ramsey, M.A., President of Magdalene College, Cambridge, formerly University Lecturer in Mathematics. Cambridge : at the University Press, 1937. (Pp. xii + 267, with 150 figures.) 10s. 6d.
- Electrical Measurements. Precise Comparisons of Standards and Absolute Determinations of the Units. By Harvey L. Curtis, Ph.D., Principal Physicist at the Bureau of Standards. International Series in Physics. New York and London : McGraw-Hill Publishing Co., Ltd., 1937. (Pp. xiv + 302, with 66 figures.) 24s. net.
- The Physics of Electron Tubes. By L. R. Koller, Ph.D., Research Laboratory, General Electric Company. Second edition. International Series in Physics. New York and London : McGraw-Hill Publishing Co., Ltd., 1937. (Pp. xviii + 234, with 84 figures and 16 tables.) 18s. net.
- The Low Voltage Cathode Ray Tube and its Applications. By G. Parr, Radio Division, the Edison Swan Electric Co. London : Chapman & Hall, Ltd., 1937. (Pp. x + 177, with 76 figures, including 6 plates.) 10s. 6d. net.
- Television Cyclopædia. By Alfred T. Witts, A.M.I.E.E. London : Chapman & Hall, Ltd., 1937. (Pp. 151, with 97 figures.) 7s. 6d. net.
- Engineering Properties of Soil. By C. A. Hogentogler, C.E., Senior Highway Engineer, U.S. Bureau of Public Roads, with the collaboration of Henry Aaron, Richard C. Thoreen, Edward A. Willis, and Adolph M. Wintermyer, Assistant Highway Engineers, U.S. Bureau of Public Roads.

- Arranged and edited by C. A. Hogentogler, Jr., Research Associate, George Washington University, Collaborator, U.S. Forest Service. New York and London: McGraw-Hill Publishing Co., Ltd., 1937. (Pp. xiv + 434, with 198 figures and 43 tables.) 30s. net.
- Gmelins Handbuch der anorganischen Chemie. 8. Auflage. Herausgegeben von der Deutschen Chemischen Gesellschaft. System-Nummer 22: Kalium, Lieferung 2: Verbindungen bis Kalium und Chlor. Berlin: Verlag Chemie, G.m.b.H., 1937. (Pp. 268, with 11 figures.) RM.31.50.
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THE ORIGIN AND NATURE OF WAVE MECHANICS¹

BY W. WILSON, PH.D., D.Sc., F.R.S.

Hildred Carlile Professor of Physics in the University of London, Bedford College

It is appropriate that the reader should be reminded at the outset of certain things which concern waves and wave propagation. We may use as an illustration a phenomenon with which everybody is familiar: the transverse waves which travel along a stretched cord. The displacement of any small part of the cord may be resolved into two components, one of them in some plane containing the fixed points between which the cord is stretched and the other at right angles to it. These two components are independent of one another and we shall consider only motions of the cord which are in or parallel to this plane. The simplest wave which can travel along the cord is one which gives it, at any instant, the shape of a sine curve (Fig. 1(a)) and it is associated with simple harmonic motions of the parts of the cord. The period and frequency of such simple harmonic motions may be represented by τ and ν respectively, so that the product $\nu\tau$ is equal to unity. The wave-length, *i.e.* the distance from crest to crest, may be represented by λ and the number of waves in the unit distance, *i.e.* $1/\lambda$, by ν' , so that the product $\lambda\nu'$ is also equal to unity. The *phase velocity* of the wave is the velocity with which a crest (or trough) travels along the cord. It is convenient to represent it by u , so that

$$u = \lambda/\tau = \nu/\nu'$$

$$\text{Phase Velocity} = (\text{Frequency})/(\text{Wave number}) \quad . \quad . \quad (1)$$

Finally we may, in accordance with the usual practice, use the term *amplitude* for the maximum value of the displacement in a simple harmonic motion.

Now any kind of wave can be regarded as a superposition of such simple waves of suitable wave-length and amplitude. That is to

¹ Based on the notes of a lecture delivered to the Mathematical and Physical Society of University College, London.

say each displacement of the cord, when any kind of wave is travelling along it, is the algebraic sum of the displacements at the point in question due to a number of simple waves. This is a consequence of a well-known theorem due to Fourier. The partial differential equation which describes the possible small motions of the parts of the cord is a *linear* one and it is a consequence of this fact that when two or more waves combine they actually do produce a resultant wave in accordance with the *principle of superposition* just described. Such a wave is illustrated in Fig. 1(c) which is the result of the superposition of the two simple waves (a) and (b).

The waves which travel along a stretched cord serve to illustrate

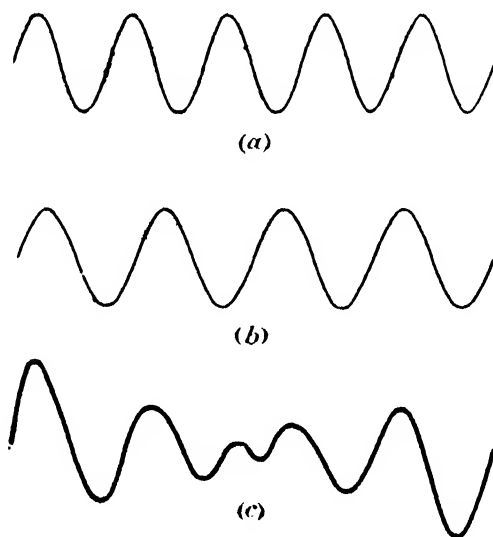


FIG. 1.

only the simplest features of waves and we are more concerned with waves in a 3-dimensional region, light waves for instance. But in speaking of light waves we must be cautious. It is very improbable that light consists of waves! The fact that it can be propagated through exhausted regions throws doubt on its undulatory nature. For wave propagation some medium is needed and since the time of the famous experiments of Michelson and Morley and the beautiful relativistic explanation of them we have been left without a luminiferous medium. For purposes of illustration however the light waves of Young and Fresnel are exceedingly convenient and useful to us and for the moment we shall think of light in very much the same way as Fresnel thought of it: namely as a wave propagation through a material or *quasi* material medium.

Regarded in this way white light may be described as a superposition of simple plane waves of all sorts of wave-lengths, periods and amplitudes, and a grating or prism makes a Fourier analysis of it—at any rate approximately—into its simple sine constituents.

Now let us turn our attention to plane—and, if preferred, plane polarised—light waves which have a sinusoidal shape, *but which extend over a limited spatial region only*. Let us further suppose that the wave-length, λ , is *very short* compared with the dimensions of the region over which the waves extend. We may conveniently call such a train of waves a *simple group*. It can be shown, with the help of Fourier's theorem, that such a group may be regarded as a superposition of infinitely extended trains of simple waves, all having the same, or practically the same, amplitude, all having wave-lengths differing inappreciably from λ and all travelling in directions nearly coincident with that in which the group is travelling. The component simple waves, whose superposition yields the simple group, destroy one another by interference outside the limits of the group. To make this description quite precise it ought to be added that the simple Fourier constituents of the group do indeed include many of widely differing wave-lengths and directions of propagation; but we may ignore these because of their inappreciable amplitudes. The simple group retains its shape as it travels onwards, approximately at any rate, as if its boundary were rigid. In the limiting case of infinitely small wave-length, λ , it does not change its shape nor spread at all and only inappreciably when λ is sufficiently small.

If ν_1' and ν_2' are the wave-numbers of any two of the simple constituents of the group and if ν_1 and ν_2 are the corresponding frequencies the *group velocity*, v , is expressed by

$$v = (\nu_2 - \nu_1)/(\nu_2' - \nu_1')$$

or

$$\text{Group velocity} = (\text{Frequency difference})/(\text{Corresponding wave number difference}) \quad \dots \dots \dots (2)$$

more usually written

$$v = \partial\nu/\partial\nu'.$$

When the medium is *dispersive*, or in other words when the *phase velocity*, u , varies with the wave-length, λ , or, what amounts to the same thing, when it varies with the wave number, ν' , the *group velocity* (2) differs from the *phase velocity* (1). The difference between group and phase velocities can easily be observed if a bath is nearly filled with water and the tap so adjusted that a drop falls about once every dozen seconds or so. Each drop will generate a group

of ripples containing some half-dozen crests and troughs. These can be observed to travel appreciably faster than the group, each crest advancing through the group and disappearing in front while new crests are created behind.

The properties of the simple group are very important and we shall summarise them :

- (i) The group has the form of a simple (*i.e.* sinusoidal) wave.
- (ii) It extends over a spatial region which is limited in all directions.
- (iii) The wave-length is almost infinitesimal compared with the dimensions of the group.
- (iv) The group advances with the velocity expressed in (2).
- (v) It maintains, approximately, its shape and size like a rigid body.

It is now necessary to inquire about the essential features of *geometrical optics*. We are not of course concerned with the peculiarities of lens systems, nor even with the laws of geometrical optics as they are commonly stated ; but with more fundamental things from which these emerge as comparatively trivial consequences. To the question : What is geometrical optics ? we may answer—and be it remembered that we are still retaining Fresnel's view of the nature of light for the sake of its present illustrative usefulness—that *we are within the domain of geometrical optics when the light consists of simple groups like that which has just been described*

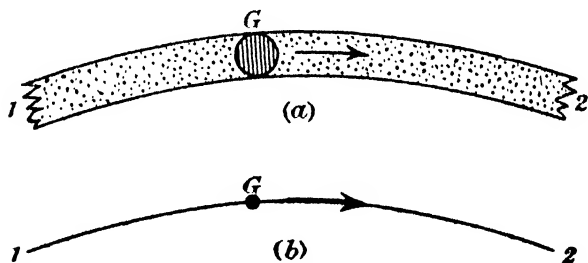


FIG. 2.

and when these groups are so small compared with the lengths of the paths they describe and with the dimensions of the lenses, apertures, etc., with which we may be working, that we may regard them (the groups) as points. In these circumstances it will be seen that the wave-length, λ , is a second order small quantity. The region swept out by one of the groups as it travels along with its characteristic group velocity will therefore approximate to a line—a straight line when the luminiferous medium is isotropic and homogeneous. In Fig. 2(a)

is shown a simple group, G , travelling between the places marked 1 and 2. The wave crests in the group are indicated by parallel lines which, in an isotropic medium, are of course perpendicular to the direction in which the group is travelling. The laws of geometrical optics apply exactly—i.e. with only second order small errors—when the group, G , is so small that it becomes practically a point as in Fig. 2(b) and the path it sweeps out is a *ray* of light.

Fermat's principle, which was anticipated in some degree by Archimedes, expresses the laws of geometrical optics in a single statement. We shall give it the following form :

The shape of the path (ray) along which G travels is such that the number of waves in it has a stationary value.

This means that the shape of the path is such that the number of waves in it may be a *maximum* or a *minimum*, but it also includes

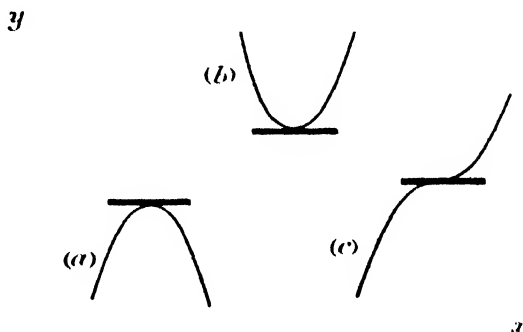


FIG. 3.

other cases. They are all illustrated in Fig. 3 in which y is some function of an independent variable x . The stationary values of y are those corresponding to the values of x where the tangent to the curve (shown by a thick line) is horizontal. The cases (a) and (b) illustrate respectively maximum and minimum values of y , while (c) illustrates the further possibilities. The number of waves between 1 and 2 (Fig. 2)—which is illustrated by the function y of the diagram—is really a function of a number of independent variables ; but we shall symbolise them shortly by the single letter, l , which may be regarded as representing distances along the ray measured from 1 (Fig. 2). The diagrams in Fig. 3 make it evident that the statement of Fermat's principle just given is equivalent to saying that the number of waves in the actual path traversed by the light (group) is equal to the number in any neighbouring path. By a neighbouring path is meant one for which the parameters

which determine its shape differ infinitesimally from those which determine that of the actual path (Fig. 4).

It is important to note that *Fermat's principle only decides what is the shape of the path or ray. It does not tell us anything about the time taken by the luminous disturbance to travel from 1 to 2* (Fig. 2). It is true that the principle is often termed the principle of *least*

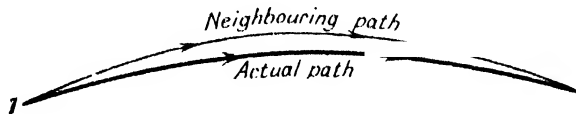


FIG. 4.

time and if the "time" referred to is that taken by a crest (or a trough) to travel from 1 to 2 it will of course have a stationary value since it is proportional to the number of waves in the path. But the time in this special sense is not in general that required by the light to get from 1 to 2.

Fermat's principle, in the form we have given it, is equivalent to the statement :

$$\left\{ \begin{array}{l} \text{Difference in the number of waves in the actual} \\ \text{and in any neighbouring path} \end{array} \right\} = 0$$

or

$$\Delta \{ \nu' \times l \} = 0, \dots \dots \dots (3)$$

where the symbol Δ is used for difference. When ν' , the number of waves per unit distance, varies from point to point we may suppose l to be a very short distance and the bracket expression to mean a sum of products like $\nu' \times l$. The statement (3) is usually written

$$\delta \int_1^2 \nu' dl = 0 \dots \dots \dots (3a)$$

It is very important to note the tacit assumption that the frequency, ν , has

(a) the same value at all points on the actual path from 1 to 2, (usually expressed in the form $d\nu = 0$)
and

(b) the same value on the actual and on the neighbouring paths (expressed by $\delta\nu = 0$). Of course ν' will in general vary from point to point, since the character of the medium may do so.

Now it is an historical fact of great interest, to students of wave mechanics especially, that a famous French savant of the eighteenth century, de Maupertuis, subsumed the laws of mechanics in a single statement, similar in form to that already given for Fermat's

principle, which no doubt suggested it to him. Maupertuis called his principle the *principle of least action*; but for reasons which the reader will appreciate we shall call it the *principle of stationary action*. It may be stated in the following way:

The shape of the path traversed by a particle¹ is such that the action has a stationary value. By action is meant the product

$$\text{momentum} \times \text{distance},$$

or, when the momentum varies from point to point, we imagine the path to be divided into a large number of very short lengths and the action will then be the sum of all products of momentum and distance for each of the short lengths, q , which make up the whole path. Maupertuis' principle may therefore be put in the form:

$$\left\{ \begin{array}{l} \text{Difference between the action for the actual and} \\ \text{that for any neighbouring path} \end{array} \right\} = 0$$

or

$$\Delta \{p \times q\} = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

where p means the momentum of the particle and q the distance it travels. And of course just as in (3) the bracket expression may mean a sum of products $p \times q$. The statement (4) is usually written in the form

$$\delta \int_1^2 p dq = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad (4a)$$

The analogous statements (3) and (3a) of Fermat's principle will be recalled and it should be noted that the application of Maupertuis' principle is governed by conditions strictly analogous to those associated with the application of Fermat's principle. Instead of

$$dv = 0,$$

and

$$\delta v = 0,$$

we have

$$dH = 0,$$

and

$$\delta H = 0,$$

where H means the energy of the particle. Maupertuis' principle is therefore limited in its application to *conservative systems*. Note the analogies between

$$\left. \begin{array}{l} p \text{ and } v', \\ H \text{ and } v, \\ q \text{ and } l \end{array} \right\} . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

¹ Of course the principle can be stated in such a way that it comprehends systems much more complex than a particle. A complete description of it is not possible within the limited scope of this essay.

Maupertuis was, in some sense, a fore-runner of Sir Arthur Eddington. The latter has recently written a book¹ in which he attempts to deduce the laws of the physical universe—it is not, one feels, a gross exaggeration to put it in this way—from the peculiarities of the intelligence of the physicist. Now Maupertuis deduced his great principle from the attributes of the Supreme Intelligence, and one appreciates on reading his work that he attributed to the Deity an intelligence very like his own (Maupertuis'). We may remark in passing that some of the illustrations he gave indicate that he did not fully appreciate the significance of the principle he discovered.

One last remark may be made about the principle of stationary action. *It only gives us the shape of the path of the particle in question. It does not for example give any information about velocities or times of passage.* In this respect too it is analogous to Fermat's principle.

If we desire to broaden the expression of Fermat's principle so that it will not only tell us what is the shape of the path of the minute groups, G , but also yield the group velocity (2) we soon realise that this can be done in only one way: The path traversed by the groups, G , from 1 to 2 and their velocities must be such as to give a stationary value to the difference

$$\left\{ \begin{array}{l} \text{Number of waves in the path} \\ \text{from 1 to 2} \end{array} \right\} - \left\{ \begin{array}{l} \text{Number of periods described} \\ \text{in the time taken by } G \text{ to} \\ \text{travel from 1 to 2} \end{array} \right\}$$

We may express this more compactly in the form

$$\Delta \{v' \times l\} - \Delta \{v \times t\} = 0 \quad . \quad . \quad . \quad (6)$$

If in applying this extended statement of Fermat's principle we retain the old conditions, namely $dv = 0$ and $\delta v = 0$, we see that both terms in (6) must vanish separately and consequently $v \times \Delta t = 0$. We shall therefore have to lay down that the time taken by a group to travel from 1 to 2 has to be the same in the neighbouring path as in the actual one. But we shall go further than this. While retaining the old condition $dv = 0$ we shall introduce a new one which is compatible with it, namely

$$\delta v = \text{a minute constant.}$$

The first term in (6) does not now vanish; but becomes

$$\{\Delta v' \times l\}$$

where $\Delta v'$ now means the change in v' which is due to δv , the change in v , and *not* the change in v' due to the difference in the positional co-ordinate, l . Similarly the second term becomes

$$\{\Delta v \times t\}$$

¹ *Relativity Theory of Protons and Electrons.*

where Δv is simply identical with the small constant we have called δv . It should not be forgotten that these bracket expressions represent sums, l and t being short intervals of distance and time respectively.

Equation (6) now becomes

$$\Delta v' \times l - \Delta v \times t = 0$$

and consequently

$$l/t = \Delta v/\Delta v', \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

and this is just the expression, as indeed we hoped it would be, for the group velocity. It is, of course, usually written

$$\frac{dl}{dt} = \frac{\partial v}{\partial v'} \quad . \quad . \quad . \quad . \quad . \quad . \quad (7a)$$

Once again let it be emphasised that the differences symbolised by Δ in (7) are *not* those due to, or associated with, changes or differences of the positional co-ordinate, or co-ordinates, l . They are due to the modified condition we have attached to the application of the principle and which we expressed in the form

$$\delta v = \text{a minute constant.}$$

This is indicated in (7a) in the conventional way by the round ∂ 's.

Now (7) or (7a) has exactly the form of one of Hamilton's canonical equations, namely

$$\text{velocity} = \Delta H/\Delta p, \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

where H is the energy and p the momentum. A very special case of this equation, which can be verified at once, is

$$v = \Delta(\frac{1}{2}mv^2)/\Delta(mv)$$

Those who are familiar with Hamiltonian dynamics will recognise in (8) the equation which is usually written

$$\frac{dq}{dt} = \frac{\partial H}{\partial p} \quad . \quad . \quad . \quad . \quad . \quad . \quad (8a)$$

But there is still something else which emerges from Fermat's principle in the extended form we have given to it. We have tacitly and quite correctly regarded v' as a function of the variables v and l , i.e.

$$v' = \text{function}(v, l).$$

This means that v can be regarded as a function of v' and l , i.e.

$$v = \text{function}(v', l)$$

and therefore any small difference or increment in the value of v ,

¹ There are, of course, as many equations of the type of (8a) as there are independent co-ordinates q .

however it may arise, can be expressed as the algebraic sum of two small differences, thus

$$\text{Diff. } v = (\text{Diff. } v)_{\alpha} + (\text{Diff. } v)_{\beta}, \quad . \quad . \quad . \quad . \quad (9)$$

where the subscript, α , is used to mark the part of $\text{Diff. } v$ which is due to a small increment of v' , which β marks the part of it which is occasioned by a change in l . But while a group, G , travels from one place on its path to another, v does not change and therefore equation (9) becomes, when applied to differences due to G travelling from one point to another on its path

$$(\text{Diff. } v)_{\alpha} + (\text{Diff. } v)_{\beta} = 0.$$

Now the former of these two terms (the one marked α) is equal to

$$\Delta v' \times \frac{l}{t}$$

in accordance with equation (7). Therefore

$$\Delta v' \times \frac{l}{t} + (\text{Diff. } v)_{\beta} = 0$$

or

$$\frac{\Delta v'}{t} = - \frac{(\text{Diff. } v)_{\beta}}{l} \quad . \quad . \quad . \quad . \quad (10)$$

The left-hand member of this equation represents the rate of change of v' as the group travels along its path. On the right-hand side the subscript β expressly marks the fact that the ratio $(\text{Diff. } v/l)_{\beta}$ is that due to the change of l only and does not include any contribution due to a change in v' . The common mathematical way of expressing such a relationship as (10) is

$$\frac{dv'}{dt} = - \frac{\partial v}{\partial l} \quad . \quad . \quad . \quad . \quad (10a)$$

and its perfect correspondence with another of Hamilton's canonical equations, namely

$$\frac{dp}{dt} = - \frac{\partial H^1}{\partial q} \quad . \quad . \quad . \quad . \quad (11)$$

will be appreciated.

Finally it may be noted that the extended form of Fermat's principle (6) may be written

$$\delta \int_1^2 (v' dl - v dt) = 0,$$

the two paths, the actual one and the neighbouring one, being not only spatially co-terminous but also, as we have seen, co-terminous

¹ See the remark in note on previous page.

in the time. On substituting p for ν' , H for ν and dq for dl we get

$$\delta \int_1^2 (p dq - H dt) = 0, \quad . \quad . \quad . \quad . \quad . \quad (12)$$

which is *Hamilton's principle*.

We have tried to show that there is a perfect analogy or correspondence between classical mechanics and geometrical optics. This was discovered by Sir William Hamilton. Indeed he was led to the discovery of his famous canonical equations and to the principle named after him by the study of problems in geometrical optics. It is an obvious inference from the existence of this perfect analogy that any purely ¹ mechanical problem can be immediately translated into one in geometrical optics: the most important features in the translation being the replacement of the momentum, p , by a wave number, ν' , or by $1/\lambda$ and of the energy, H , by a frequency, ν , or by $1/\tau$. We may in fact replace the momentum, p (in classical mechanics), by $h\nu'$ (or h/λ) and the energy, H , by $h\nu$ (or h/τ) where h is *any* (sufficiently small) constant. We shall naturally not be misled into a belief in the physical reality of the waves associated with the mechanical problem. We have simply observed an extraordinary and exact correspondence between the equations describing classical dynamical problems and those describing wave propagation in the particular limiting case which geometrical optics exemplifies.

Fermat's principle begins to fail when λ ceases to be a second order small quantity compared with the dimensions of the apparatus we are using, the lenses, apertures, optical paths, etc. In other words the laws of geometrical optics begin to be inadequate when the apparatus is not large enough by comparison with λ or when the times involved are not large enough compared with the period τ . When λ is not larger than a first order small quantity we help ourselves out with *Huygens' principle*; ² but when our apparatus, lenses, etc., are of the same order of magnitude as λ even this fails us and we have to deal with the optical problem by finding suitable solutions of the partial differential equation which governs it.

This failure of geometrical optics has its parallel in mechanics. The laws of classical mechanics begin to break down when they are applied to sufficiently small systems: atoms, electrons, etc., as was first recognised by the great German master of theoretical physics, Max Planck, who founded the quantum theory. Bearing

¹ Problems involving the generation of heat are not purely mechanical in the sense in which the term is used here.

² In its correct form, due to G. Kirchhoff.

in mind the analogy between geometrical optics and classical mechanics and the fact that both fail under similar circumstances we are naturally led to suggest a new principle: *all mechanical problems may be translated into optical problems*. When it happens that the problem is a micromechanical one, the corresponding optical problem is not one of *geometrical optics*, but of *undulatory optics* and thus we find ourselves at last within the domain of *wave mechanics*. The new principle may fittingly be called *Schroedinger's principle* after Erwin Schroedinger, Planck's successor in the Chair of Theoretical Physics in the University of Berlin, who, although he did not originate wave mechanics, contributed very greatly to its development and who thoroughly appreciated the nature and importance of the Hamiltonian analogy.

We find already in Newton's *Opticks*, first published in 1704, some very remarkable previsions of modern views about light.¹ His definition of a "ray" at the beginning of the book and his subsequent references to it make it extraordinarily like the simple groups, *G*, of Fig. 2. It had a periodic phenomenon associated with it, the fits of easy reflexion and easy transmission, the frequency of which we must identify with our ν . Planck's energy quanta have a close affinity with Newton's "rays." Interchanges of energy between simple harmonic systems and consequently also the absorption and emission of radiant energy (light) occur, according to Planck's quantum theory, in integral multiples of $h\nu$, where h is a certain constant (Planck's constant) the value of which (6.54×10^{-27} ergs. \times sec.) he determined from data provided by the experimental investigation of full radiation. Einstein's hypothesis that light actually consists of small bundles of energy (now called *photons*) each equal to $h\nu$ is a natural corollary to Planck's hypothesis and its adoption may be said to have rehabilitated in a large measure Newton's views about light. It accounted admirably for photo-electric phenomena and later for the Compton effect which it may be said to predict; but it made the phenomena of interference and diffraction of light very difficult to understand. It was this difficulty which led Louis de Broglie to suggest, about 1924, that in light we have a phenomenon in which both waves and particles are involved. He imagined the energy, as did Einstein, to be localised in the particles (photons) each of them having the amount $h\nu$, while the waves in some way guided the photons along paths normal to the wave fronts. His next step is best described in his own words: "But if for a century we have neglected too much the corpuscular

¹ See Messrs. Bell's reprint of the 4th edition and the Introduction to it by Professor E. T. Whittaker.

aspect in the theory of light in our exclusive attachment to waves, have we not erred in the opposite direction in the theory of matter? Have we not wrongly neglected the point of view of waves and thought only of corpuscles?"¹ Thus de Broglie was led to associate waves (now called *de Broglie waves*) with all elementary particles and in particular with electrons and to predict the electron diffraction phenomena now so familiar in consequence of the experimental work of Davisson and Germer, G. P. Thomson, E. Rupp and their successors. In order to meet certain requirements of the theory of relativity he assigned to the waves associated with a particle the *phase velocity*

$$u = c^2/v,$$

where c is the velocity of light in empty space and v is the velocity of the particle. This expression for the phase velocity led him to the expression we have already found for the momentum, p , of the particle, namely

$$p = h/\lambda = h\nu',$$

since

$$p = mv = mc^2/u$$

and therefore, since mc^2 is the relativistic expression for the energy of the particle and is consequently equal to $h\nu$,

$$p = h\nu/u = h\nu'$$

All this is in complete agreement with the Hamiltonian correspondence already described and has been abundantly verified experimentally in the case of electrons. de Broglie also discovered the identity of the velocity of the particle and the group velocity of the associated waves.

Before the development of wave mechanics the quantum theory was an incoherent association of disconnected and rather arbitrary hypotheses which were insufficient in many ways and did not build up a logical whole. The work of de Broglie and Schroedinger has removed these reproaches. Schroedinger's method was substantially that adopted in problems of undulatory optics (or in undulatory problems generally). He started out from a linear partial differential equation, *Schroedinger's equation*, which cannot be adequately treated within the limits of this article; but only illustrated. The simplest example of a wave is described by

$$\psi = A \cos 2\pi(\nu'q - \nu t), \quad . \quad . \quad . \quad . \quad (13)$$

in which q measures distances normal to the wave front and in

¹ L. de Broglie: *Wave Mechanics*, p. 3, translated by H. T. Flint (Methuen).

which A , ν' and ν are constants. We can find its mechanical analogue by translating in the way suggested by the Hamiltonian correspondence :

$$\psi = A \cos \frac{2\pi}{h}(pq - Ht) \quad . \quad . \quad . \quad (13a)$$

Since H and p are constants this represents the case of a particle free from forces—or, equally well, a rigid body rotating about a fixed axis under no forces. For reasons which are familiar to all who have studied oscillating systems, especially electrical ones, and which need not be given here, it is both permissible and convenient to replace (13a) by

$$\psi = A e^{\frac{2\pi i}{h}(pq - Ht)} \quad . \quad . \quad . \quad (13b)$$

The associated differential equation is

$$\frac{\partial^2 \psi}{\partial t^2} + \frac{H^2}{p^2} \frac{\partial^2 \psi}{\partial q^2} \quad . \quad . \quad . \quad (14)$$

and generally of course it is from the partial differential equation that we start out. The method used to solve such equations is quite old.¹ We shall illustrate it by applying it to (14). It consists in finding a particular solution of the form :

$$\psi = TQ,$$

where T is a function of t only and Q is a function of q only. Substitution in (14) yields

$$\frac{1}{T} \frac{d^2 T}{dt^2} = - \frac{H^2}{p^2 Q} \frac{d^2 Q}{dq^2}$$

each side of which must be equated to an arbitrary constant m . Then we get

$$T = a e^{\pm \sqrt{m} t},$$

$$Q = b e^{\pm \sqrt{m} \frac{p}{H} q},$$

and consequently

$$\psi = A e^{\sqrt{m} \left(t \pm \frac{p}{H} q \right)}$$

is a particular solution : a , b and A being arbitrary constants. Obviously

$$\sqrt{m} = 2\pi i \nu = 2\pi i H/h$$

and in the special case of a rigid body rotating about a fixed axis,

¹ The mathematician, B. Riemann, has given some very interesting historical information in his work *Ueber die Darstellbarkeit einer Function durch eine trigonometrische Reihe* on the efforts of Brook Taylor, Daniell Bernoulli, d'Alembert and Euler to solve the problem of the vibrating cord and similar problems which are governed by just such an equation as (14).

q is the angular co-ordinate and since an increment of q equal to 2π leaves the configuration of the system unchanged the function Q must not be altered thereby. The condition which ensures this is

$$\sqrt{m} \frac{p}{H} \cdot 2\pi = 2\pi n,$$

where n is any integer. Therefore we have another expression for \sqrt{m} namely

$$\sqrt{m} = inH/p,$$

and on equating the two we get for the angular momentum, p :

$$p = nh/2\pi$$

which is a familiar relationship even in the older quantum theory. We may write for the relationship between H and p

$$H = p^2/2I,$$

I being the moment of inertia. Hence

$$H = n^2 h^2 / 8\pi^2 I.$$

These discrete values for the momentum and energy are just those which appeared in the older theory as a consequence of the familiar condition $\oint p dq = nh$.

The function ψ which represents the state of the system in a sense which will appear presently, is a sum of products of such functions T and Q (*proper functions*) each associated with an appropriate value of \sqrt{m} (*proper value*). The proper functions and proper values are not new things invented to serve the purposes of wave mechanics, but have long been known and called by these names.¹

What is the significance of the amplitude, A , in (13a) or (13b)? To answer this question we must give up the view about the nature of light which was held by Young and Fresnel, and which indeed we have only used for purposes of illustration, and adopt the view that the physical entities in a beam of light are the photons. The waves are just as visionary as were those we found so useful in the comparison of classical mechanics and geometrical optics. They constitute a sort of picture of the kind of calculations we do. The rules for determining where the photons go, in an interference experiment for example, are precisely the same as those which determine the positions of the fringes on the assumption of the undulatory nature of light. Now the square of the amplitude, i.e. A^2 , measures the intensity of the light and therefore its value in a bright fringe is a measure of the number of photons

¹ The corresponding German terms are *Eigenfunktion* and *Eigenwert*.

reaching it in the unit time. But the wave, *i.e.* all of it that is coherent or whose parts are capable of interfering with one another, represents a *single photon* and we are therefore forced to regard the value of A^2 at any place as a measure of the probability that the photon is there and we adopt this view of the significance of the amplitude of the waves associated with electrons and other elementary particles.

When the velocity of a particle is known the associated wave system must be a simple group such as we have described and if it happens that its momentum, p , is large the associated wave-length, λ , which of course is equal to h/p , will be correspondingly small and the condition that it shall be small compared with the dimensions of the group can be satisfied even when the group itself is so small as to be indistinguishable from a point (Fig. 2b). We can in these circumstances assign accurately both a position and a momentum to the particle. This is the macrophysical case in which a measurement of λ and a consequent determination of the constant h from $h = \lambda p$ is impossible and for which the precise individual values of both h and λ are of no consequence; but only their ratio h/λ which of course must be equal to p . In order to admit of measurement, a wave-length must not be too small compared with the dimensions of an essential part of the apparatus used, namely the grating spacing or its equivalent. If the momentum of the particle is very small the condition that λ shall be small compared with the dimensions of the simple group can only be satisfied when the group is large. There is now, according to our theory, a limit to the accuracy with which we can know the position of the particle at any instant. There must be an uncertainty of the order of magnitude of the dimensions of the group, since the probability of its being at a particular place is measured by A^2 which has practically the same value at all points within the group. On the other hand when we have an accurate knowledge of the position of the particle at some instant, the wave system (wave-packet) representing it must necessarily be very small in its dimensions. This is because there is *some* probability (measured in fact by $\psi\bar{\psi}$ where $\bar{\psi}$ is the complex quantity which is conjugate to ψ) that the particle is at *any* place within the wave system representing it, and our accurate knowledge of its position means that it is certain that the particle is *not outside* a certain small region and that therefore ψ vanishes outside this small region. But the Fourier analysis of such a small wave-packet, in the microphysical case at any rate, brings out plane waves travelling in all sorts of directions and of widely differing wave-lengths. Consequently we cannot have

accurate information about the momentum (and velocity) of the particle since such information implies a wave system consisting of waves of a narrow range of wave-lengths and travelling very nearly in the same direction—a simple group in fact. We cannot, it seems, know both the position and momentum of a particle accurately at the same time. This is the *uncertainty principle* of Bohr and Heisenberg which we may state more precisely as follows :

$$\left. \begin{array}{l} \text{The order of magnitude of the product} \\ \Delta p \cdot \Delta q \\ \text{is at least as great as that of Planck's con-} \\ \text{stant, } h, \end{array} \right\} \cdot \cdot \cdot (15)$$

Δp and Δq being respectively the uncertainties in the measured values of the momentum, p , and of the corresponding positional co-ordinate, q .

To locate a small thing like an electron we are forced to do something which will interfere with its momentum and the more accurately we locate it the more violent and incalculable is this interference. Similarly in order to measure its momentum (or velocity) we are forced to use a method which necessarily entails uncertainty about its position—an uncertainty which is all the greater the more accurate is the measurement of the velocity of the particle. If we use the Doppler effect to measure the velocity of a small particle we must use light of long wave-length, so that the photons in it have low energies and do not interfere with the velocity we are measuring. But then any apparatus using radiation of long wave-length must necessarily have very low resolving power and be quite useless for accurately locating anything that is small. Conversely we should require light of very short wave-length (gamma rays) for high resolving power and accurate determination of position; but the high energy of the individual photons in it would seriously interfere with the momentum of the particle whose position we are finding. It appears to be an essential characteristic of the physical world that when anything happens which reveals very accurately the values of certain quantities, *e.g.* momenta or energies it must necessarily hide the values of the corresponding conjugate quantities; so that the *law of causality* fails, if we mean by causality the possibility of predicting future events from information which is now available. We can only estimate the probabilities of future events, and in the macrophysical world most of these probabilities are very high and represent practical certainties.

This outline of the nature of wave mechanics would be incomplete without at least a brief reference to the form of quantum mechanics developed by W. Heisenberg about the same time as

de Broglie began his work on wave mechanics, or a little earlier. The two forms of micromechanics are very different in their outward form and appeared to have nothing in common, except the puzzling feature that they led to identical results, until some years later when Schroedinger succeeded in establishing their mathematical identity. We can in fact derive Heisenberg's mechanics from wave mechanics by a method of which the following sketch gives a somewhat rough and incomplete notion. If we differentiate (13*b*) partially with respect to q we get

$$\partial\psi/\partial q = (2\pi i/\hbar)p\psi \quad . \quad . \quad . \quad . \quad (16)$$

and thus we see that the operation $\partial/\partial q$ is equivalent to the operation of multiplication by $(2\pi i/\hbar)p$, at all events when performed on ψ . Consider now

$$\frac{\partial}{\partial q}x\psi$$

where x is any function containing q as an independent variable. The expression means the result of first multiplying ψ by x and then differentiating the product with respect to q :

$$\frac{\partial}{\partial q}x\psi = x\frac{\partial\psi}{\partial q} + \left(\frac{\partial x}{\partial q}\right)\psi,$$

the brackets on the right indicating that the $\partial/\partial q$ within them operates on x only. Therefore

$$\frac{\partial}{\partial q}x\psi - x\frac{\partial\psi}{\partial q} = \left(\frac{\partial x}{\partial q}\right)\psi$$

or

$$\frac{\partial}{\partial q}x - x\frac{\partial}{\partial q} = \left(\frac{\partial x}{\partial q}\right)$$

which asserts that the operation $\frac{\partial}{\partial q}x - x\frac{\partial}{\partial q}$ is equivalent to the operation of multiplication by $\frac{\partial x}{\partial q}$. In consequence of (16) therefore

$$\frac{2\pi i}{\hbar}(px - xp) = \left(\frac{\partial x}{\partial q}\right) \quad . \quad . \quad . \quad . \quad (17)$$

The special case, $x = q$ yields

$$\frac{2\pi i}{\hbar}(pq - qp) = 1 \quad . \quad . \quad . \quad . \quad (17a)$$

Similarly we may infer

$$\frac{2\pi i}{\hbar}(Hx - xH) = \left(\frac{\partial x}{\partial t}\right), \quad . \quad . \quad . \quad . \quad (18)$$

$$\frac{2\pi i}{\hbar}(Ht - tH) = 1 \quad . \quad . \quad . \quad . \quad (18a)$$

These equations, which are only a sample as it were of a larger whole, are not so crazy as they look! If we replace such differential quotients as $\partial x/\partial q$ or $\partial x/\partial t$, etc., wherever they occur in Hamilton's canonical equations, by the corresponding "crazy" expressions in (17) or (18) we get the equations of Heisenberg's theory in the form it has acquired in the work of Born, Jordan and Dirac. Their madness disappears when we represent p , q , H , etc., by *matrices*. The matrix, H , in particular is a diagonal one and its elements are the energy values of the stationary states of the older theory, the proper values of Schroedinger's theory or the *spectral terms* of the spectroscopist.

The wave mechanics of de Broglie was the immediate outcome of his efforts to reconcile the corpuscular and undulatory features of light. Heisenberg's work was inspired, directly or indirectly, by the philosophy of Ernst Mach which forbids, even more sternly than did that of Newton, the adoption of hypotheses of any kind or the introduction of notions which lack the quality that may be described as "observational value." Both forms of quantum dynamics have now impressive achievements standing to their credit and it must give great satisfaction and pleasure to Planck, who twenty-five years ago prophesied that the full success of the work then devoted to his quantum theory would probably only accrue to a later generation, to contemplate the outcome of his epoch-making ideas.

THE BIOLOGY OF LIGHT-PRODUCTION AMONG THE ARTHROPODS

By N. S. ROYSTON MALOEUF, M.S., PH.D.

Sterling Fellow in Animal Biology, Yale University; Contribution from the Zoological Laboratory, Cornell University, and the Osborn Zoological Laboratory, Yale University

. . . all the fire emitted by wood and other combustibles when burning, existed in them before in a solid state, being only discovered when separating.

BENJAMIN FRANKLIN.

A LUMINESCENT body is one which radiates light at a low temperature and whose light is not the result of the absorption of radiant (light, heat, actinic) energy, *e.g.* the light emitted by living organisms and the freshly cut surfaces of sodium and potassium metals. A *phosphorescent* body is one which gives off light at a low temperature after the absorption of radiant energy, *e.g.* the alkaline earth sulphides plus metal impurities. A *fluorescent* body is one which gives off light at a low temperature only during the time it is being irradiated, *e.g.* chitin in the presence of ultra-violet rays, and eosin. An *incandescent* body is one which emits light because of its high temperature; for a black body the total radiation varies directly with the fourth power of the absolute temperature.

Since the light of luminous animals is independent of external irradiation and since neither phosphorescence nor fluorescence can be produced in a non-luminous extract of the animal, the light of such is a luminescence. Chemiluminescences invariably require oxygen or ozone for their production, *e.g.* that of phosphorus, freshly cut surfaces of metallic sodium and potassium, and animal luminescence (Harvey, 1919).

(a) DISTRIBUTION AND STRUCTURE OF THE LIGHT-PRODUCING ORGANS

For a treatment of the earlier literature on this topic, de Kerville (1890) and Mangold (1910-14) should be consulted.

1. *Crustacea*.—Light-producing organs have been found among the Ostracoda, Copepoda, Schizopoda, and Decapoda. Luminescence in the ostracod, *Cypridina hilgendorffii*, is extracellular.

The luminescent organ in the latter is composed of maxillary gland cells (Kanda, 1920). Each cell of the organ opens by a separate pore with a valve. Upon the contraction of certain muscles, the secretion is forced out and luminesces in the sea water (Harvey, 1919). In the deep-sea shrimp, *Acanthephyra debelis*, the light organs are scattered on the surface of the body (Harvey). The shrimp, *Systellaspis*, possesses a large luminous gland which secretes a luminous material into the sea water (Harvey, 1931a). This species occurs at depths between 600 and 800 fathoms off the coast of Bermuda (Harvey, 1931a). Luminescence at abysmal depths may be used for lumination, though Kemp (1910) has noted that the vast majority of marine animals possessing photophores (including decapods) live at the surface or at intermediate depths and never occur at the bottom, at least in deep water.

2. "*Myriapoda*" (*Centipedes and Millipedes*).—The enlarged light-producing, hypodermal cells of "myriapods" have been treated in another paper (see Maloeuf, 1937).

3. *Hexapoda*.—Carpenter (1854) noted that luminous insects are nearly restricted to two families of the Coleoptera: (i) The Elateridæ, or "fireflies," have many luminous species, probably all of which are confined to the New World. (ii) The Lampyridæ, or "glow-worms," have over 200 known luminous species, most of which occur in America. According to Carpenter, both sexes of the former family are equally luminescent, while the females of the latter family are more intensely luminous.

The luminous organ in many of the Elateridæ is probably a modification of the fat body (cf. Williams, 1916–17, and Okada, 1935) and lies above the sixth and seventh abdominal sterna. It consists of: (i) A dorsal layer of reflector cells, white in appearance owing to the presence of crystals of xanthin, urates or both¹; (ii) a ventral mass of large cells (the light-producing cells) containing photogenic granules (not fat granules); (iii) large tracheal trunks and tracheoles; (iv) nerve fibres; (v) non-pigmented and somewhat translucent sternal plates beneath the light-producing cells. "The luminous matter," said Carpenter (1854), "consists of little granules, and is contained in minute sacs, covered with a transparent horny lid. These sacs are mostly composed of a close network of finely divided tracheæ; which also ramify through every part of the granular substance." The "lid," in this phrase, probably implies the

¹ In the larva of a tipulid fly, *Bolitophila luminosa* (Wheeler and Williams, 1915), part of each Malpighian tubule is photogenic. This is an interesting modification when one realises that the essential feature of the reflector layer is insoluble purine crystals.

reflector layer. There is a pair of light organs in *Pyrophorus*, a West Indian elaterid, on the lateral tergal margins of the prothorax and also a single light organ on the ventral anterior median region of the abdomen (Harvey and Stevens, 1928).

Luminescence is present in the interior of *Pyrophorus* eggs prior to any embryonic differentiation. Dubois (1885) observed this to be the cause of the error of some observers who had stated that light is given off by the whole body of the adult. This statement had already been refuted by others who, Dubois considered, must have noted only males. The egg of *Lampyrus*, also, emits light when within the ovary and freshly laid eggs are luminous. The light does not come from luminous material adhering to the egg when it is laid, but from within the egg itself (Carpenter, 1854, and Harvey, 1919). The larval light-organ persists and glows in the pupa and is absorbed only at the time the adult emerges. Now, certain prominent biologists (such as Kuhnt, 1907; Pierantoni, 1914 and 1918; Buchner, 1914 and 1926) have claimed that luminescence in insects is due to the presence of intracellular symbiotic bacteria. Dubois' (1914) numerous attempts at bacterial cultures were negative and Harvey and Hall (1929) banished this notion when they found that "the adult luminous organ developed perfectly from larvæ having both light organs removed." The luminous granules in the light-producing cells are, therefore, not bacteria but luminous substance. There is, however, no reason to assume that bacteria play a nil factor in the luminosity of all species of Metazoa.

Luminescent insects also occur among the Collembola (*Lipura*, *Amphorura*, *Neanura*), Neuroptera (*Teleganoides*, *Coenis*), Diptera (*Bolitophila* and *Ceroplatus* larvæ), Hemiptera, Lepidoptera and other orders.

(b) BEHAVIOUR

Only luminous bacteria, fungi, and a few fish produce light continuously. Other forms emit light at intervals depending upon the periods of stimulation (Harvey, 1919). Squeezing *Pyrophorus* elaterids causes the organs to glow brilliantly for a considerable period of time (Harvey and Stevens, 1928, and Harvey, 1931*b*).

In Asia for February 1924 is an article by Carveth Wells on his experiences in the Malay Archipelago (Morse, 1924): "The air was full of extraordinary fireflies. About every fifteen minutes these flies separating into two armies, one settling on the trees growing on the left bank of the river and the other on the right. Then, when I had decided that the fireflies had gone to bed for the night, the whole army on the left bank gave one big flash in

perfect unison, which was immediately answered by one big flash on the right. How these flies managed to keep time absolutely beats me, but they did so, though there must have been thousands of them stretching along the river-banks for a hundred yards or more. The illumination was so strong that the branches of the trees could be seen quite distinctly." In a paper read before the American Society of Zoologists, Buck (1935 and 1937) described his studies on the periodicity and diurnal rhythm in the firefly, *Photinus pyralis*. "In nature, males of *P. pyralis* ordinarily flash every evening between 7 and 9 p.m. The time of flashing is correlated with temperature and light intensity. Males which have been in strong light long flash immediately if the intensity is sufficiently reduced, regardless of the time of the day, showing that the regular evening flashing period can be modified. Males kept continuously in darkness do not flash. If, however, they are exposed to weak light they flash (regardless of the time of the day) provided they have previously been in darkness 24, 48, 72, or 96 hours but not if they have been in darkness 12, 36, 60 or 84 hours. If males which have been in darkness less than 24 hours are exposed to weak light and left in it they do not flash until the sum of the time spent in darkness and the time spent in weak light is equal approximately to 24 hours. It is thus apparent that there exists in the firefly an inherent diurnal periodicity which is manifested by periods of flashing which recur at 24-hour intervals and which persist for at least 4 days in the uniform environment of the dark-room. It is also clear that, although in the field this periodicity coincides with the diurnal cycle of changes in light intensity, it is not actually linked to any specific hour of the day." By "inherent" Buck does not mean "inherited" but implies the 24-hour rhythm produced by internal stimuli. It has been noted that when *Dixippus* eggs are placed under constant light conditions the adults no longer exhibit any periodicity in the migration of hypodermal pigment granules (Schleip, 1914, 1920). Similar experiments are necessary in order to determine whether or not the internal stimuli producing the periodical flashing in fireflies is inherited. Perkins (1931) found that female larvæ and adults of *Lampyrus noctiluca* exposed continuously to light stopped glowing about the third day, while those receiving diffuse light by day, and those in continued darkness continued to glow at the normal hours (10 p.m. to 4 a.m.) for about two weeks. A similar periodicity thus exists in the Lampyridæ. By means of photocell analysis, Harvey (1931b) observed a rhythmic fluctuation of light intensity during the emission of light from the firefly, *Pyrophorus*. Because

of its rapid rate, this fluctuation was attributed to rhythmic nervous discharges from a photogenic centre.

Lampyris noctiluca and *Photuris pennsylvanica* larvæ and adults can be made to luminesce experimentally by nipping the ventral nerve cord and by single induction shocks (Perkins, 1931, and Snell, 1931). Brown and King (1931) measured the intensity of the light produced by *Photuris pennsylvanica* as the result of a single electrical stimulus. A series of responses follow a single stimulus with an increasing time interval between each response (Fig. 1) until the responses, declining in intensity, eventually fade

100

80

60

40

20

0 10 30 50 70 90

FIG. 1.—The magnitude of the photogenic response of *Photuris pennsylvanica* initiated by a single electrical stimulus. Ordinate: intensity of flash (units unstated). Abcissa: time scale (10 units = 0.833 seconds). (After Brown and King.)

away. The decreases in light intensity after a stimulus implies a difference in the velocity of the reaction in the light-producing cells which, as Brown and King consider, can depend only on differences in the concentrations of luciferin, luciferase, or oxygen; of two of these factors; or of all three factors. This consideration issues from the fact that we know a number of things: (1) Molecular oxygen is necessary for luminescence, *i.e.* the process

is an oxidation; (2) a substrate, luciferin, is oxidised through the agency of an enzyme classified among the aerobic oxidases and termed luciferase; (3) according to the phenomena of mass action, the velocity of a chemical reaction varies directly with the concentrations of the reacting components. Owing to the fact that the luciferin-luciferase reaction shows a similar relationship *in vitro*, where the oxygen available is constant, to that depicted in Fig. 1, Brown and King concluded that the declining concentration of the luciferin-luciferase system was the determining factor in the "die-away" portion of the response. Because, however, of the

much slower decline in luminosity in the above *in vitro* conditions than in the intact animal and because of the facts stated in the next paragraph, it is probable that the decline in luminosity in the intact animal is due to a decrease in the concentration of oxygen in the vicinity of the photogenic cells.

Why should the luciferin and luciferase components of the luminescing cells of arthropods not react all the time and thus produce light continuously as do bacterial and fungus luminescent cells? For one thing, the luminescent cells of arthropods are not as directly exposed to free oxygen as are bacterial cells. This is clearly shown from the fact that exposing the isolated luminescent organ of a firefly to air causes the organ to luminesce continuously. We have also already noted that flashing can result from nervous or direct electrical stimulation. In this connection, the demonstrations of Wigglesworth (1929, 1930, 1931, 1932) on the regulation of the oxygen supply to the cells of tracheates, by means of the movement of fluid in the tracheoles, should be borne in mind. Now, Snell (1931) suggested that the control of flashing in insects is due to the regulating mechanism of the nervous system on the amount of oxygen admitted to the photogenic cells. Variation in the intensity of a flash may, under such conditions, be brought about by differences in the oxygen supply to the luminescent cells. Snell considers that "the tracheal end cell is certainly the responsive mechanism in this control," but Harvey (1919) stated that "it is difficult to determine if the nerves supply the tracheal end cells or the photogenic cells." If, as Wigglesworth seems to have clearly shown, the withdrawal of fluid from the lumen of tracheoles depends upon an increase in the osmotic pressure of the surrounding tissue fluids, it is difficult to see how nervous stimuli to the tracheal end cells could produce such an effect. Possibly, as the result of nervous stimuli, the metabolic rate of the photogenic cells is raised with the consequent liberation of metabolites. These would cause a withdrawal of fluid from the tracheoles of the photogenic cells which, in turn, would supply the cells with more oxygen.¹ It is interesting to note, at this point, that Kanda (1920*b*) found that the intensity of light produced by a firefly, *Luciola vitticollis*, is greater when air is introduced after evacuation than when the animal had been in air for some time. This may be due to the oxygen debt built up by the tissues (including the photogenic cells) when in a vacuum. The metabolites (e.g. lactic acid), caused to accumulate because of the anaerobic conditions, would raise the

¹ Cogent experimental evidence that such is the case will be presented in a forthcoming paper by the writer.

osmotic pressure of the tissue fluids and thus cause more air to be drawn into the tracheoles. Creighton (1926) found that injecting a 1 : 1,000 solution of adrenalin into a firefly causes a prolonged brilliant glow which persists for several hours after injection. It was suggested that the cause of the effect is the contraction of the muscle fibres of the tracheal end cells and, through this action, the enlargement of the tracheole with a consequently greater supply of oxygen to the luminous tissue. Such muscle fibres, however, very probably exist only in fancy. The effect of adrenalin may have been due to a rise in the metabolic rate with a resultant liberation of metabolites by the photogenic cells.

What is the significance of luminescence in the economy of an animal? After reviewing the literature on the subject, Gazagnaire (1890) came to the conclusion that the intensity of luminescence in geophilid chilopods is intimately correlated with the time of sexual activity. Carpenter (1854) had already remarked that the same holds true for insects. The increase in the intensity of luminescence at such a time may be due to a raised rate of metabolism at this time; or, in the words of Carpenter, "the activity of this combustion is stimulated by anything which excites the vital functions of the individual." The notion that luminescence has a secondary sexual function in chilopods has already been banished (see Maloeuf, 1937). In fireflies, on the other hand, the case is evidently different. Thus, according to Mast (1923), "the female (firefly) in response to a flash of light produced by the male turns the ventral surface of her abdomen toward him no matter where he may be located; and the male in response to a flash of light produced by the female, turns and flies or walks directly toward her no matter where she may be located. In both, the extent and the direction of turning, i.e. the character of the reaction, depends upon the location on the retina of the image produced by the flash." See also Osten-Sacken (1861).

(c) CHEMICAL PHENOMENA

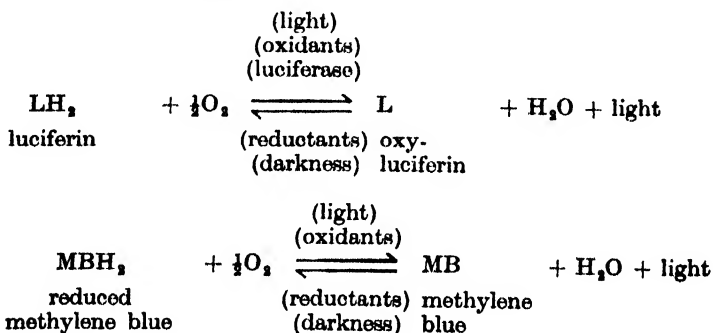
1. LUMINESCENCE AN OXIDATIVE PROCESS.

"The phosphorescence," wrote Carpenter (1854), concerning luminescence in fireflies, "appears to be occasioned by the slow combustion of a peculiar organic compound, the production of which is dependent for its continuance upon the life and health of the animal; the activity of this combustion is stimulated by anything which excites the vital functions of the individual, and it is particularly influenced by the energy of the respiratory process. If the opening of the trachea which supplies the luminous sac be

closed, so as to check the access of air to its contents, the light ceases; but if the sac be lifted from its place, without injuring the tracheæ, the light is not interrupted. In all active movements of the body, in which the respiration is energetic, the light is proportionately increased in brilliancy. If the luminous segments be separated from the rest of the body, they continue phosphorescent for some time." Carpenter thus definitely established for insects what Boyle (1667) had discovered approximately two centuries earlier for bacteria, namely, that air is necessary for luminescence. Ofsianikof (1863), also, found that the luminosity of *Lampyris noctiluca* ceases *in vacuo* but recommences on the re-admission of a little air and becomes very dull in an atmosphere containing an excessive amount of carbon dioxide. Temporary immersion in glycerin also caused a cessation of luminescence possibly due to a plugging of the spiracles. The condition was quite reversible, however, upon washing with water, in which glycerin is soluble. The work of Dubois, of Kastle and McDermott (1910) and of Harvey (1916a and 1920) on *in vitro* aqueous suspensions of extracted luciferin-luciferase all goes to show very definitely that oxygen is directly necessary for luminescence. Contrary results were presented by Kanda (1920a) who noted that the intensity of light produced by an aqueous suspension of luciferin-luciferase from the Japanese ostracod, *Cypridina hilgendorffi* (Kanda, 1920a), is strongest and lasts longest in water saturated with hydrogen from which other gases, including oxygen, had been discharged. The intensity of light produced by a luciferin-luciferase suspension of this animal was weakest and lasted least in water saturated with oxygen. Although Kanda admitted that *very little* oxygen might have been present in spite of elaborate precautions, he boldly concluded that the production of light by *Cypridina hilgendorffi* is not the result of oxidation. Four years prior to Kanda's work, Harvey's (1916a) experiments, in which oxygen was replaced by hydrogen, showed that oxygen is necessary for light production in *Cypridina hilgendorffi*. Harvey, then, also called attention to the fact that every other organism studied was found to require oxygen for luminescence. In reply to Harvey's criticism, Kanda (1920b) endeavoured to justify his previous results by checking his technique on a Japanese firefly, *Luciola vitticollis*. In this form, no light was produced by the isolated photogenic organs in an atmosphere of pure hydrogen or nitrogen, or in a vacuum. The intensity of light was greatest in an atmosphere of pure oxygen. Kanda thus concluded that his technique was surpassingly faultless and that the production of light by *L. vitticollis*

is the result of oxidation while that in *Cypridina* is not. Biologists were now faced by a new enigma—that of finding out why *Cypridina* can luminesce without oxygen while this phenomenon in *Luciola* imperatively requires oxygen. That this problem was only man-made soon became apparent when Harvey (1920) showed that Kanda's technique was not without blemish. All traces of the oxygen usually present in commercial hydrogen gas were removed by passing the hydrogen over hot platinum coil. Under such conditions the oxygen present as an impurity, combines with an equivalent amount of hydrogen and forms water. When gaseous hydrogen so treated was used, all light production by *C. hilgendorffii* completely disappeared. "The luminescent secretion of *Cypridina hilgendorffii* will still give off much light if hydrogen containing only 0.4 per cent. oxygen is bubbled through it. . . . At 7 mm. of oxygen (i.e. 1 vol. per cent.) the light of *Cypridina* is as bright as if the solution were saturated with air (152 mm. oxygen)" (Harvey, 1919). In 1923 Harvey and Morison described a method for measuring the concentration of oxygen to allow just perceptible luminescence of luminous bacteria. The value was 1 part by weight of oxygen dissolved in 37×10^8 cc. of sea water. Shapiro (1934) studied the light intensity of luminous bacteria as a function of oxygen pressure.

Alkali, within limits, favours the oxidation of luciferin to oxyluciferin with the resultant production of light, while acid favours the reduction of oxyluciferin to luciferin with the consequent extinction of the glow (Harvey, 1919). These facts are in accordance with oxidations and reductions in general. Harvey considered the change similar to the oxidation and reduction of methylene blue. It may be represented thus :



The oxidation of luciferin of the beetle, *Pholas*, with the production of light, can be produced without the agency of luciferase and "merely" by the addition of an inorganic oxidant such as potassium

permanganate. Aluminium, zinc, or magnesium powders or other inorganic reducing agents will reduce oxyluciferin to luciferin as they will reduce methylene blue to the colourless compound. In both cases the reactions are reversible.

The activity of aerobic oxidases is destroyed by cyanides above certain concentrations. On the other hand, the activity of anaerobic oxidases, that is oxidases which do not accelerate oxidations produced by molecular oxygen (*i.e.* dehydrogenases) are not affected by cyanides. Luciferase is quite evidently an aerobic oxidase and we would, therefore, expect its activity to be demolished by cyanides. While N/20 KCN does not extinguish the luminescence of *Cypridina*, it lessens its brightness (*i.e.* presumably lessens the mass of active luciferase). Dilutions of N/250 to N/100 KCN do not affect the intensity of illumination of a *Cypridina* luciferin-luciferase suspension appreciably (Harvey, 1916*a* and *b*). The cause of the almost nil effect of KCN on the action of this aerobic oxidase is problematical.

2. LUCIFERINS AND LUCIFERASES

(*a*) *Properties*.—To Dubois belongs the credit for first discovering the presence of the substrate, luciferin, and the enzyme, luciferase, involved in luminescence. In 1885, he found that even an aqueous extract of the photogenic organ of a lampyrid beetle will luminesce in the presence of oxygen. It was thus shown that cellular structure is not essential for the production of light and that the latter, therefore, is not a "vital" function. Such an extract, however, was continuously luminescent so long as it endured, there being no periodicity in the production of light. From what has been said concerning the oxygen supply the reason for this is quite apparent. It was also first shown by Dubois (1887*a* and *b*) that the production of luminescence requires the presence of at least four substances, one of which had been recognised to be oxygen. Two separate solutions were obtained from an aqueous extract of the photogenic organs of fireflies. Upon dialysis through celloidin neither the dialysate nor the residual solution luminesced. When both solutions were again mixed light was produced. This at once established the presence of at least two distinct substances. The substance in the residual solution was destroyed at temperatures of 60° C. or above and was soluble in water but not in petroleum ether or benzene. The substance in the dialysate was relatively thermostable, and soluble in water, petroleum ether, or benzene. Dubois thus termed the substance in the dialysate "luciferin" and that in the residual solution "luciferase" since he soon observed

that the latter substance exhibited the properties of an enzyme (i.e. a protein with catalytic properties).

The fourth substance required for luminescence is water. Kastle and McDermott (1910) dried the photogenic material of a firefly *in vacuo*, over concentrated sulphuric acid. In the dry state no light was emitted. After keeping the material quite dry for over thirteen months luminescence was produced upon moistening with water. Similar results were obtained by Harvey (1916a) on *Cypridina hilgendorffi*. The photogenic substances (luciferin and luciferase), oxygen, and water, are thus necessary for the production of luminescence in organisms.

There was a time when Harvey (1916a) contradicted Dubois's work at its very foundations by considering that, contrary to Dubois's conception, luciferase itself is the source of light and is not an enzyme causing light production by the oxidation of luciferin. Harvey's statements grew from experiments in which light was obtained from *Cypridina* luciferase by substances incapable of oxidation (e.g. pure sodium chloride, magnesium sulphate, chloroform, ether, oleic acid, and pilocarpin—all in aqueous solution). Harvey thereby adopted new names after deciding that those of Dubois were unfit: (i) "Photogenin" (= luciferase of Dubois), or the light producer, and (ii) "photophelein" (= luciferin of Dubois), or light assister. While Harvey was busy criticising Kanda on the oxidative nature of animal luminescence, Kanda also, quite successfully, was having his turn. Thus, Kanda (1920) found that *Cypridina* luciferase, when mixed with a pure aqueous solution of chloroform, ether, sodium chloride, or magnesium sulphate, never produces light. Kanda's criticism, however, appeared two years late, since Harvey (1918), upon further work with *Cypridina*, had already readopted Dubois's terms of luciferin and luciferase. Harvey's error concerning this matter lay in the manner of his preparation of a luciferin-"free" solution. He allowed a luciferin-luciferase solution to stand in air till all light ceased when he assumed that the luciferin was consumed, for light was not produced until further luciferin was added. Upon the addition of sodium chloride, magnesium sulphate, ether, or chloroform (a fine array of different substances) to the solution in which the luciferin was supposedly consumed, light was again produced. It was later found, however, that a luciferase solution separated from luciferin by dialysis did not act in this manner. Harvey (1918), therefore, concluded that luciferin probably consists of two substances, one of which is set free to be acted upon by luciferase when sodium chloride, magnesium sulphate, ether, or chloroform are added.

There are luciferins and luciferases. Thus, luciferin from the firefly, *Photuris*, will produce light with luciferase from the firefly, *Pyrophorus*, and vice versa. But the luciferin and luciferase of *Cypridina*, an ostracod, will not produce luminescence with firefly luciferase or luciferin, respectively. *Cypridina* luciferin, furthermore, differs from that of *Pholas* (a beetle) in that the latter will oxidise with light production when acted upon by various oxidising agents tried (e.g. potassium permanganate, hydrogen peroxide, oxyhæmoglobin, but not with nascent oxygen in the absence of luciferase) and will not emit light with *Pholas* luciferase. Extracts of many non-luminous animals will oxidise *Pholas* luciferin with light production, but not do so with *Cypridina* luciferin (Harvey, 1919 and 1928). Luciferin of the shrimp, *Systellaspis*, will not give light with luciferase of the ostracod, *Cypridina*, nor will *Cypridina* luciferin luminesce with the luciferase of *Systellaspis* (Harvey, 1931a).

Plants also, apart from bacteria, contain luciferases, for "if one mixes a test tube containing pyrogallol solution + hydrogen peroxide with potato or turnip juice or almost any plant extract, a yellowish luminescence appears. The plant extract loses the power to cause such luminescence on boiling and the peroxidase will not dialyse. It is, of course, comparable to luciferase and acts on the thermostable, dialysable pyrogallol-hydrogen peroxide mixture, which is comparable to luciferin. . . . Although many hydroxy-phenol and amino-phenol compounds can be oxidised by peroxidase and hydrogen peroxide, only pyrogallol and gallic acid will oxidise with light production" (Harvey).

Table I represents Harvey's (1919) summary of his studies on the properties of the luciferin and luciferase of *Cypridina hilgendorffi*. His results have been confirmed by Kanda (1921 and 1924). Luciferase exhibits very definitely protein properties, or "if luciferase is not a protein it is so closely bound up with a protein that it cannot be separated." This quotation can be said to represent our present state of knowledge concerning all enzymes, although Sumner (1935 and 1937) and Northrop (1937) appear to have shown, in the case of urease, pepsinase, trypsinase, catalase and amylase, that the protein itself is the enzyme. Harvey estimated that 1 gm. of a luciferase can accelerate the oxidation of 10,000 gm. of luciferin. The fact that the activity of luciferase is gradually demolished in the reaction does not prevent its being classed among the organic catalysts (enzymes). Enzymes, in general, are gradually used up in the reactions they generate and accelerate. The chemical nature of luciferin is not as yet determined (Anderson, 1933, 1935, 1936) in

TABLE I
PROPERTIES OF LUCIFERASE AND LUCIFERIN
(from the work of Harvey on *Cypridina*)

Property.	Luciferase.	Luciferin (more simple than luciferase).
<i>Salting out :</i>		
Saturation with NaCl . . .	Not precipitated	Not precipitated
$\frac{1}{2}$ saturation with $(\text{NH}_4)_2\text{SO}_4$. .	Slightly precipitated	"
Saturation with $(\text{NH}_4)_2\text{SO}_4$. .	Completely precipitated	Nearly completely precipitated
<i>Solubility :</i>		
Ethyl alcohol 90% . . .	Insoluble	Soluble
" " 70% . . .	"	"
" " 50% . . .	Slightly soluble	"
Acetone 90% . . .	Insoluble	"
Ether . . .	"	Insoluble
Chloroform . . .	"	"
Xylol . . .	"	"
<i>Alkaloidal reagents :</i>		
Phosphotungstic acid . .	Completely precipitated	Very nearly completely precipitated
Picric acid. . .	Nearly precipitated	Not precipitated
<i>Heavy metal salts :</i>		
Basic lead acetate . . .	Completely precipitated	Not completely precipitated
<i>Acids and alkalis :</i>		
NaOH . . .	Not precipitated	Not precipitated
Trichloroacetic acid . . .	"	"
HCl, after 16 hr. boiling . .	Destroyed "	Hydrolysed
<i>Heat :</i>		
60° C. . .	Irreversibly destroyed	Not destroyed
Boiling . . .	" "	" "
Boiling with 4% H_2SO_4 for 10 hr. . .	Destroyed	" "
Do. for 24 hr. with 4% H_2SO_4 . .	"	Destroyed
<i>Enzyme action :</i>		
Trypsin, erepsin, amylase, urease, sucrase, pepsinase, rennin . . .	Destroyed only by pepsin (?), by trypsin, erepsin, and something in spleen and liver extracts	Not destroyed
<i>Biuret reaction</i> . . .	Positive	Negative
<i>Dialysis</i> . . .	Will not dialyse through collodion	Will dialyse through collodion

spite of the statement of Kanda (1930) that it is a phospholipid. Nearly complete precipitation by a saturated solution of ammonium sulphate or phosphotungstic acid, insolubility in fat solvents and hydrolysis by prolonged boiling with hydrochloric acid, indicate protein properties. On the other hand, solubility in concentrated alcohol and acetone, non-digestibility by proteolytic enzymes, and the absence of a biuret reaction are not protein characters.

(b) *Distribution in an Organism.*—While luciferin is apparently found in various tissues of *Cypridina hilgendorffii*, luciferase is strictly localised in the photogenic cells (Harvey, 1919). This is in contrast with the phenomena of melanin formation in the elytra of *Leptinotarsa* beetles, where the enzyme tyrosinase is distributed but the substrate localised (Gortner, 1911). Luciferin, but not luciferase, is also found, according to Harvey (1916a), in non-luminous species of *Cypridina*. On the other hand, Kanda (1920) disagreed with Harvey but agreed with Dubois by finding luciferin solely in the photogenic cells of *Cypridina* and not in non-luminous species. The apparent presence of luciferase in plants, as indicated by the experiments of Harvey, and the substitution of pyrogallol + hydrogen peroxide for luciferin is, in this connection, noteworthy.

(d) PHYSICAL PHENOMENA

1. *Efficiency in Light Production.*—In the *Philosophical Transactions of the Royal Society of London* for 1671, Vol. I and page 603 is a brief article bearing the authorship of John Templer and the title, "Some Observations concerning Glow-worms." The note runs thus: "Mr. T. also persuaded himself that he perceived a degree of heat from the insect, when shining in its fullest splendour." In contrast to the foregoing statement we have the following in a semi-popular recent article by Parlin (1935): "The ratio between the intensity of the light (of a firefly) thus produced and the amount of matter oxidised is the largest known to science, the efficiency being better than 95 per cent. The best man-made light is less than one per cent. ! Most of the energy in the latter case is radiated in the form of heat. . . . How the firefly can radiate 'cold light,' free from the enormous amount of heat which is present in all man-made sources of light, is a problem which has baffled science for many years, and its solution will revolutionize our lighting industry."

The efficiency of a light source can be defined by: (i) The percentage of visible wave-lengths in the total amount of radiation emitted, i.e. the amount of visible radiation emitted divided by the total (heat, visible, and actinic) radiation; or (ii) by the amount of light produced in relation to a given expenditure of energy (Harvey, 1919). Both definitions are identical. Since an additional amount of heat evolved by a firefly during luminescence could not be measured even by use of most refined technique (Langley and Very, 1890; Langley, 1902; Coblentz, 1912) and since photography has shown that all the light waves emitted are within the visible region (see below), the efficiency of light production in a firefly

is very close to 100 per cent. In view, however, of the facts that oxygen is directly necessary for luminescence, that all oxidations are exothermic, and that the postulation of synchronous endothermic reactions during luminescence is quite unnecessary, it is intellectually unsatisfying to believe in an efficiency of 100 per cent. Some heat, no matter how small, must be lost. We should here learn a lesson from the attempts at the measurement of heat evolution from nervous tissue—a very appreciable quantity which, until fairly recently (Downing, Gerard, and Hill, 1926), was considered nil (Bayliss, 1915). Reactions accelerated by enzymes are very efficient and only in a very few cases has the amount of heat evolved as the result of enzymatic action been capable of measurement. At this point, Franklin's statement, "being only discovered when separating," mentioned at the beginning of this article is noteworthy. When we know how enzymes accelerate reactions we shall be more prepared to "revolutionize our lighting industry" by producing light in similarly efficient fashion on a large scale. It is remarkable that the researches of relatively obscure men in small laboratories have, from time to time, yielded results of deepest consequence. Luminescence which is the outcome of the accelerating agency of enzymes has been termed bioluminescence.

2. *Intensity of the Light.*—In an *in vitro* suspension of luciferin-luciferase, the intensity of light varies directly with the concentration of the suspension. Even as little as one gram of the dry photogenic material of *Cypridina hilgendorfi* will yield visible light when suspended in 1,700,000,000 gm. (or c.c.) of water (Harvey, 1916a). The maximum brightness of one of the prothoracic light organs of the intact firefly, *Pyrophorus*, is 0.0002 candle at 20° C. (Harvey and Stevens, 1928). Coblentz (1912) recorded an intensity variation for the firefly, *Photinus pyralis*, varying between 0.020 and 0.0025 candle with the predominating value at about 0.0025 candle. This insect will sometimes glow steadily with a glow as low as 0.000020 candle in intensity (Harvey, 1919). The average brightness of a Pennsylvania firefly is 0.00067 candle (Parlin, 1935). During the Spanish-American war, Colonel Gorgas, according to Parlin, "used the light from a bottle of fireflies to carry out an operation."

The light intensity produced during luminescence is measured by a very sensitive photoelectric cell and compared with that of a standard lamp.

3. *Wave-lengths Represented.*—All light waves emitted by the luminescence of a firefly, *Photinus*, are within the range of the visible spectrum. The light produced by this animal extends only to the beginning of the blue, forming a band extending through the

red to the end of the green with a wave-length range of 6700 Å. to 5100 Å. (Harvey, 1919). See also Young (1870), Langley and Very (1890), Ives (1910), and Ramdas and Venkiteshwaran (1931). The light of various species is not all of the same wave-length consistency. "When luciferase and luciferin of two species of ostracods having different coloured luminescences are intermixed, the resulting luminescence is determined by the animal supplying the luciferase. In the firefly and in ostracods, increase in temperature shifts the colour of the luminescence toward the longer wave-lengths," i.e. towards the red (Polimanti, 1911, and Harvey, 1924).

SUMMARY

1. A luminescent body is one which radiates light at a low temperature and whose light is not the result of the absorption of radiant energy.

2. Among arthropods luminescence occurs among various crustaceans, insects, centipedes, and millipedes.

3. Luminescence is controlled by the oxygen supply to the luminescent cells. As the result of nervous stimuli (which are often periodical), the metabolic rate of the photogenic cells is raised with the consequent liberation of metabolites. The latter, by raising the osmotic pressure of the tissue fluids, cause a withdrawal of fluid from the tracheoles of the photogenic cells and, thus, supply the cells with more oxygen.

4. Unlike centipedes, luminescence in beetles evidently serves for sexual attraction.

5. Luminescence is an oxidative process normally caused by the action of an aerobic oxidase (luciferase) upon a substrate (luciferin) of as yet undetermined chemical constitution, in the presence of oxygen when the substrate is in solution.

6. There are several luciferins and luciferases, which do not necessarily interreact.

7. Since luminescence itself liberates no apparent heat and is not accompanied by the discharge of any other form of energy apart from visible light, it is *apparently* 100 per cent. efficient. While this testifies to the marked efficiency of enzymatically performed reactions, some additional heat, however, no matter how small and inappreciable, must be lost during luminescence.

REFERENCES

- ANDERSON, R. S. (1933), *J. cell. comp. Physiol.*, **3**, 45.
 — (1935), *J. gen. Physiol.*, **19**, 301.
 — (1936), *J. cell. comp. Physiol.*, **8**, 261.

- BAYLISS, W. M. (1915), "Principles of General Physiology" (London, 850 pp.).
- BOYLE, R. (1867), *Phil. Trans. roy. Soc.*, **2**, 206.
- BROWN, E. S., and C. V. KING (1931), *Physiol. Zool.*, **4**, 287.
- BUCHNER, P. (1914), *Zool. Anz.*, **45**, 17.
- (1926), "Tierisches Leuchten und Symbiose" (Berlin, 58 pp.).
- BUCK, J. B. (1935), *Anat. Rec. Suppl.*, **64**, 66.
- (1937), *Physiol. Zool.*, **10**, 45.
- CARPENTER, W. B. (1854), "Principles of Comparative Physiology" (London, 770 pp.).
- COBLENTZ, W. W. (1912), Publ. No. 164, Carnegie Inst., Wash., D.C.
- CREIGHTON, W. S. (1926), *Sci.*, **63**, 600.
- DUBOIS, R. (1885), *Compt. rend. Soc. Biol.*, **37**, 559.
- (1887a), *ibid.*, **4**, 564.
- (1887b), *Compt. rend. Acad. Sci.*, **105**, 690.
- (1914), "Le Vie et la Lumière" (Paris).
- DOWNING, A. C., R. W. GERARD, and A. V. HILL (1926), *Proc. roy. Soc. Lond.*, **B 100**, 223.
- GAZAGNAIRE, J. (1890), *Mém. Soc. zool. France*, **3**, 136.
- GORTNER, R. A. (1911), *Amer. Nat.*, **45**, 743.
- HARVEY, E. N. (1916a), *Amer. J. Physiol.*, **42**, 318.
- (1916b), *ibid.*, **42**, 324.
- (1918), *J. gen. Physiol.*, **1**, 133.
- (1919), "The Nature of Animal Light" (Philadelphia, 182 pp.).
- (1920), *Amer. J. Physiol.*, **51**, 580.
- (1924), *ibid.*, **70**, 619.
- (1928), *J. biol. Chem.*, **78**, 369.
- (1931a), *Zoologica, Sci. Contr. N.Y. Zool. Soc.*, **12**, 71.
- (1931b), *J. gen. Physiol.*, **15**, 139.
- and R. T. HALL (1929), *Sci.*, **69**, 253.
- and T. F. MORRISON (1923), *J. gen. Physiol.*, **6**, 13.
- IVES, H. E. (1910), *Physical Rev.*, **31**, 637.
- KANDA, S. (1920), *Amer. J. Physiol.*, **50**, 544.
- (1920a), *ibid.*, **50**, 561.
- (1920b), *ibid.*, **53**, 137.
- (1921), *ibid.*, **55**, 1.
- (1924), *ibid.*, **68**, 435.
- (1930), *Sci.*, **71**, 444.
- KASTLE, J. H., and F. A. McDERMOTT (1910), *Amer. J. Physiol.*, **27**, 122.
- DE KERVILLE, H. G. (1890), "Les Animaux et les Végétaux Lumineux" (Paris, 327 pp.).
- KUHNT, P. (1907), *Ent. Wochenschr.*, **24**.
- LANGLEY, S. P. (1902), *Ann. Astrophys. Observ.*, **2**, 5.
- and F. W. VERY (1890), *Amer. J. Sci.*, ser. 3, **40**, 97.
- MALOEUF, N. S. R. (1937), *Quart. Rev. Biol.*, **13** (in press).
- MANGOLD, E. (1910-14), "Die Produktion von Licht." (In Winterstein's *Handb. d. vergl. Physiol.*, vol. 3, no. 2, pp. 225-392.)
- MAST, S. O. (1923), *J. exp. Zool.*, **38**, 109.
- MORSE, E. S. (1924), *Sci.*, **59**, 163.
- NORTHROP, J. H. (1937), *Physiol. Rev.*, **17**, 144.
- OFSIANIKOF, P. (1863), *Bull. Acad. imp. de St. Petersb.*, **7**, 55.
- OKADA, V. K. (1935), *Mem. Coll. Sci., Kyoto*, **10 B**, 209.

- OSTEN-SACKEN, BARON (1861), *Stettiner entom. Zeit.*, **22**, 54.
- PARLIN, W. A. (1935), *Scientific American*, **32**, 230.
- PERKINS, M. (1931), *Nature, Lond.*, **128**, 903.
- PIERANTONI, U. (1914), *Rendic. Accad. Sci. di Napoli*, Fasc. 1-4.
- (1918), *Scientia*, **23**, 43.
- POLIMANTI, O. (1911), *Z. f. Biol.*, **55**, 505.
- RAMDAS, L. A., and L. P. VENKITESHWARAN (1931), *Nature, Lond.*, **128**, 726.
- SCHLEIP, W. (1914), *Zool. Jb. allg. Zool.*, **30**, 45.
- (1920), *Zool. Anz.*, **52**, 151.
- SHAPIRO, H. (1934), *J. cell. comp. Physiol.*, **4**, 313.
- SNELL, P. A. (1931), *Sci.*, **73**, 372, 373.
- SUMNER, J. B. (1935), *Annual Rev. Biochem.*, **4**, 37.
- and A. L. DOUNCE (1937), *Sci.*, **85**, 366.
- TEMPLER, J. (1871), *Phil. Trans. roy. Soc.*, **1**, 603.
- WHEELER, W. M. and F. X. WILLIAMS (1915), *Psyche*, **22**, 36.
- WIGGLESWORTH, V. B. (1929), *Nature, Lond.*, **124**, 986.
- (1930), *Proc. roy. Soc. Lond.*, **B 106**, 229.
- (1931), *Biol. Rev.*, **6**, 181.
- (1932), *Proc. roy. Soc. Lond.*, **B 108**, 354.
- WILLIAMS, F. X. (1916-17), *J. Morph.*, **28**, 145.
- YOUNG, C. A. (1870), *Amer. Nat.*, **3**, 615.

STRUCTURE OF ORGANIC MOLECULES BY X-RAY ANALYSIS

By J. MONTEATH ROBERTSON, M.A., Ph.D., D.Sc.

Davy Faraday Laboratory, Royal Institution, London

THE immense variety of the compounds of carbon is due to the capacity that element has of combining with itself as well as with other elements. Early in the history of organic chemistry, however, it was recognised that the character of a compound depends upon the *arrangement* of the atoms in the molecule, as well as upon their relative numbers. Thus although ethyl alcohol and dimethyl ether have the same molecular formula, the substances have entirely different properties. With the work of van't Hoff, the idea of the comparatively rigid, tetrahedral distribution of valencies in the carbon atom was introduced, and the subject of structural chemistry rapidly built up. The central problems became the determination of the space arrangement of the atoms in the various kinds of molecules, and the subsequent syntheses of these molecules from the elements.

The object of X-ray analysis is also to find how atoms are arranged in space. When a beam of X-rays is made to pass through a crystal of any substance, the molecules in regular array act as a diffraction grating. By measuring the positions of the diffracted rays and making use of the known wave-length of the radiation, the distances between the molecules in the crystal can be calculated, and so we can get a rough idea of their size and shape. But the intensities of the various orders of the diffracted beams depend upon the detailed structure of the grating, that is, upon the way in which the atoms are arranged in the molecule and the molecules grouped together. In X-ray analysis we try to discover this arrangement from a study of the intensities of the diffracted X-ray beams. The structural problem is thus similar to that of organic chemistry, but the experimental data from which the investigator works are radically different in the two cases, and so it is of particular interest to see how the results correspond.

In this article we consider first the relation between the struc-

tural formulæ of organic chemistry and the information that can be obtained by X-ray analysis of the crystalline compounds. The X-ray method is then described in more detail, and examples are given of some structures recently determined in this way.

It should be said at once that so far there is no absolutely direct method known for solving the X-ray problem in the general case. But in special cases and by various means a solution can be obtained, and one thing is quite clear. When an arrangement of atoms is suggested, by whatever indirect means, as the structure which exists in the crystal, then this structure can immediately be tested to see whether it is correct or not, and if it is correct there is no doubt about it. The number of atoms in the smallest unsymmetrical portion of the crystal may be large, and the position of each atom is determined by three co-ordinates. This gives the number of parameters which define the structure. But the intensity of every ray diffracted by the crystal defines a relation existing among these parameters, and the number of diffracted rays which can be measured from any crystal is always very much greater than the number of atoms in the unit of pattern. Although the number of parameters may be large, it follows that the number of equations defining those parameters is still larger, and so when a possible solution is suggested there need be no doubt as to whether it is correct.

At first it might be thought that when a chemical structure is suggested for any compound, its correctness might be immediately tested by X-ray methods, if crystals are available. The matter is not quite so simple as this, for two reasons. In the first place the structural formula expresses a *relative* space arrangement of the atoms in the molecule. It does not give the distances between the atoms, and what is more important, as rotation is possible about non-cyclic single bonds, it cannot in general give an absolute configuration for the molecule. The molecule is usually quite a flexible affair, and what its exact shape will be when packed into a crystal cannot be foretold. In the second place, the smallest unit in the crystal may consist not of one molecule but of a group of molecules arranged together. And even in the simplest case, if the crystal unit consists of one rigid molecule of known configuration, we have still to consider the orientation of this molecule with respect to the crystal axes to which the co-ordinates of the atoms can be referred.

In spite of these difficulties the X-ray method has already been extensively used as a way of testing the general validity of proposed structures for organic compounds. It is chiefly applicable to structures containing closed ring systems where the possible configurations of the molecule are limited, and in these cases the

most elementary measurements of the distances between identical molecules in the crystal, giving the size of the "unit cell" which contains the molecule, are sometimes sufficient to decide between alternative formulæ. The results are even more valuable when combined with information obtained from other physical properties of the crystals. Good examples of such work are to be found in Bernal and Crowfoot's investigations on the structure of the sterols [1] and Iball's work on the carcinogenic hydrocarbons [5].

In this article, however, we shall be more concerned with those exact determinations of structure by X-ray analysis where the position of every atom has been found. In most of these cases the structural formula was already known by chemical methods, and in every case the X-ray analysis has confirmed the correctness of the chemical result. When we consider the vast progress of organic chemistry during the past hundred years and the innumerable structures which are accurately known, there may seem little chance of the X-ray method breaking new ground in this direction. The structures still unknown or in considerable doubt are nearly all very complicated ones. Had X-ray analysis been invented half a century earlier, the history of chemistry might have been different. As it is, however, very considerable progress has been made in the technique of X-ray analysis in a comparatively short time, and it seems quite a reasonable expectation that in the future X-ray methods may at least considerably supplement, if they do not supersede, the analytical methods of organic chemistry where complicated structures are concerned. The forces of organic chemistry could then be concentrated more directly on problems of synthesis.

The application of X-ray methods to complex unknown or partly known structures is one direction in which advance may be made. Another lies in the really detailed and accurate study of quite simple and chemically well-known structures. During the last ten years great progress has been made in the theoretical study of molecular structure by quantum mechanics [13]. The theory of valency has received a new and somewhat less empirical expression, and the properties and stability of certain compounds can to some extent be explained in terms of the new conceptions. But for any quantitative test of the new theories it is of the utmost importance to know accurately the distances between atoms, and how this distance varies when the atoms are held together by the different kinds of valency bonds recognised by chemistry. Purely chemical experiments cannot give such information, but this is precisely what is provided by quantitative X-ray analysis.

Before describing some of the recent results, we must consider the X-ray method a little more closely. For details reference should be made to the standard works of the Braggs, Compton, Wyckoff, and others, and to a forthcoming article in the *Physical Society's Reports on Progress in Physics*, Vol. IV.

The crystal consists of a regular three-dimensional array of identical units, and each of these units may be an atom, a molecule, or as is most usual, a small group of molecules related by certain symmetry operations. For the present we may think of this crystal unit as being simply a single molecule, whose structure we wish to investigate. If we choose some definite point or atom on this molecule, then this point together with the corresponding points on all the other identical molecules form a space lattice. The crystal planes to which we shall refer are simply planes drawn to pass through a number of these lattice points, and the spacing of any plane is the shortest distance between two identical planes. Such planes can be drawn in all directions, and in fact they form an infinite series, of smaller and smaller spacing, as the distances between the lattice points through which they are drawn become greater.

When an X-ray beam passes through the crystal each molecule scatters some of the radiation in all directions. But owing to the regularity of the structure there are certain directions, which make definite angles with the direction of the incident beam, along which the scattered rays reinforce each other by the principle of optical interference and finally build up a diffracted beam of measurable intensity. This happens when a certain integral relation connects the wave-length of the radiation, λ , the spacing of the plane, d , and the angle of incidence of the rays θ . This is the well-known Bragg law

$$n\lambda = 2d \sin \theta,$$

n being the order of the diffraction. The diffracted beam is usually called a "reflection," the angle which it makes with the crystal plane being the same as the angle of incidence of the original or primary beam.

To derive the above relation, which enables us to measure the distances between the planes, or between layers of identical molecules, we need consider only the wave scattered by the molecule as a whole. This wave, however, is a composite disturbance, made up from the contributions scattered by all the electrons in the molecule. Under the influence of the incident beam each electron radiates a wave, and the wave we have been considering as scattered by the whole molecule is actually compounded from the wavelets

scattered by all the electrons in the molecule. Now if all these electrons were concentrated at a point, or lay exactly on the crystal plane, the component wavelets would reinforce each other and the resultant intensity would be a maximum. Actually, as the electrons are spread about in the molecule, some of the component wavelets are cancelled out or partially cancelled out by interference, and the resultant intensity is reduced. The more diffuse the distribution, the smaller the resultant intensity will be. In a single atom, for example, most of the electrons are concentrated in a small space near the centre, and in simple structures where a single atom is the crystal unit the intensities of the diffracted beams are high. But if we increase the temperature, the thermal movements of the atoms effectively spread out the distribution to some extent and the intensities of the diffracted beams decrease.

We see, therefore, that these intensities give a measure of the extent to which the scattering matter, or electrons, are distributed in the structure. A mathematical relationship can be established between the distribution of scattering matter in the structure and the intensities of the diffracted beams, which was first pointed out by Sir William Bragg in 1915 [3]. We have seen that the crystal is essentially a periodic structure, built up by the repetition of identically arranged molecules in all directions. This periodic medium can therefore be analysed by Fourier's method into a series of harmonic terms, the periods of the terms corresponding to the spacings of all the possible crystal planes. It can then be shown that the amplitudes of the various terms are related to the intensities of the X-ray reflections from the crystal planes. By measuring the intensities of the X-ray reflections it is therefore possible to evaluate the coefficients in the Fourier series. Considerable difficulties are involved, because the relation between the measured intensity and the absolute value of the Fourier series coefficient is not a simple one. A large amount of experimental and theoretical work has been done on the subject, however, and the coefficients can generally be evaluated.

When this stage has been reached, it is not yet possible to sum the series and so calculate the electron distribution in the structure. We still require to know the relative phase constants of the different terms. Unfortunately, the X-ray method can not in general supply this information directly. The reflections are recorded separately, with the crystal in different positions, and so there is no direct way of measuring the phase constants in the case of a single crystal. But these unknown phase constants are often restricted to certain definite values by the symmetry of the

crystal. If the unit of structure has a centre of symmetry, for example, then each term in the Fourier series which represents the structure must conform to this symmetry, that is, either a peak or a trough of each of the component sinusoidal distributions of density must coincide with the centre of symmetry. These two possibilities are taken into account by attaching a positive or negative sign to the coefficient.

The difficulty of determining these unknown signs or phase constants can be overcome in various ways. We may assume that the structure is built up from atoms, where the density is highly concentrated. The chemical evidence will tell us the number and kinds of the atoms present, and the magnetic and optical properties of the crystal may indicate certain likely arrangements. Various possible structures can then be tested until a certain agreement is obtained between the measured and calculated values of the X-ray intensities. This roughly determined structure may be quite sufficient to decide between the alternative possible values of the phase constants, down to quite weak reflections, and a Fourier synthesis of the structure can then be carried out, using the measured amplitudes and the calculated phase constants. The results will give quite an accurate picture of the structure and the positions of the atoms can be settled with some certainty. If still more accuracy is required, the phase constants may be calculated again from these new results, and a few more weak terms can be included in the series. The synthesis can then be repeated. By a process of successive approximation we thus become independent of the precise details of the initial assumptions made about the structure, and the final result is virtually an X-ray picture of the molecule. Other more direct methods of analysis are occasionally possible, and we shall refer to some of these later.

The complete expression of the structure is given by a three-dimensional Fourier series whose terms correspond to all the possible crystal planes. Such a series is difficult to evaluate numerically owing to the large number of terms, and so in practice a two-dimensional series is usually employed, which represents a projection of the structure in a given direction. The coefficients in such a series correspond to the reflections from all the crystal planes which are parallel to the axis along which the projection is made. In such projections of a structure some atoms are often hidden behind others, but the complete structure can usually be worked out by piecing together the results of two or more projections along different crystal axes.

We may illustrate the application of this method first by refer-

ence to some aromatic hydrocarbon structures which have been determined in recent years [15, 16]. Although such molecules are complicated by reason of the large number of atoms which they contain, the possible configurations are limited by the chemical structural formula and it has been possible to determine the precise

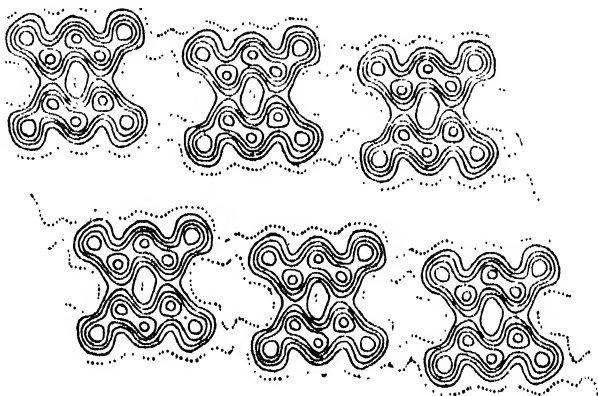


FIG. 1.—Durene.

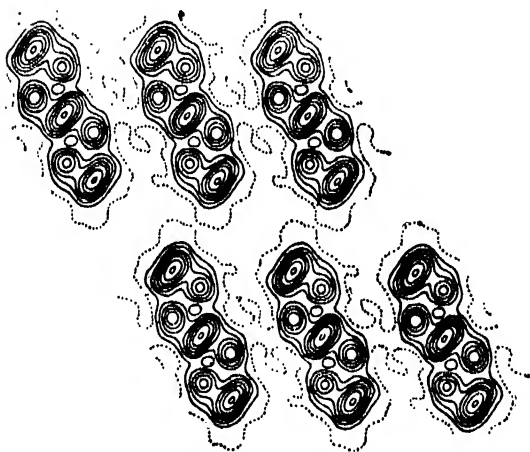
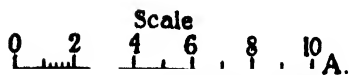


FIG. 2.—Naphthalene.



SCALE OF FIGS. 1-4.

positions of the atoms in many cases by X-ray methods. The earliest determination of this kind was that of hexamethylbenzene by K. Lonsdale in 1929 [10], which did not, however, make use of the Fourier series method.

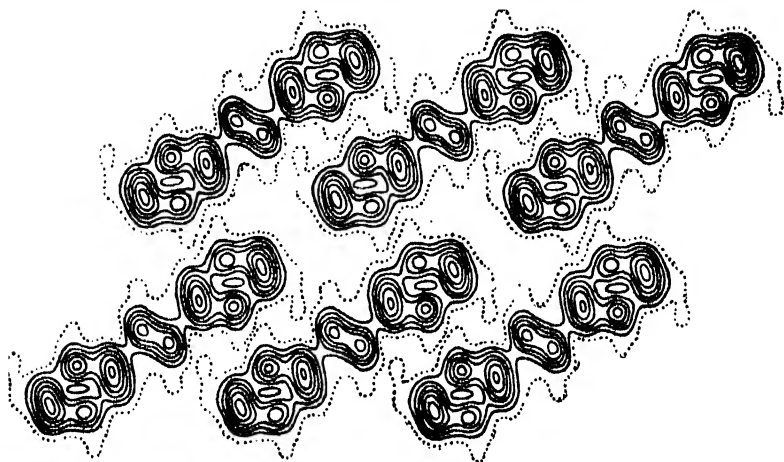


FIG. 3.—Dibenzyl.

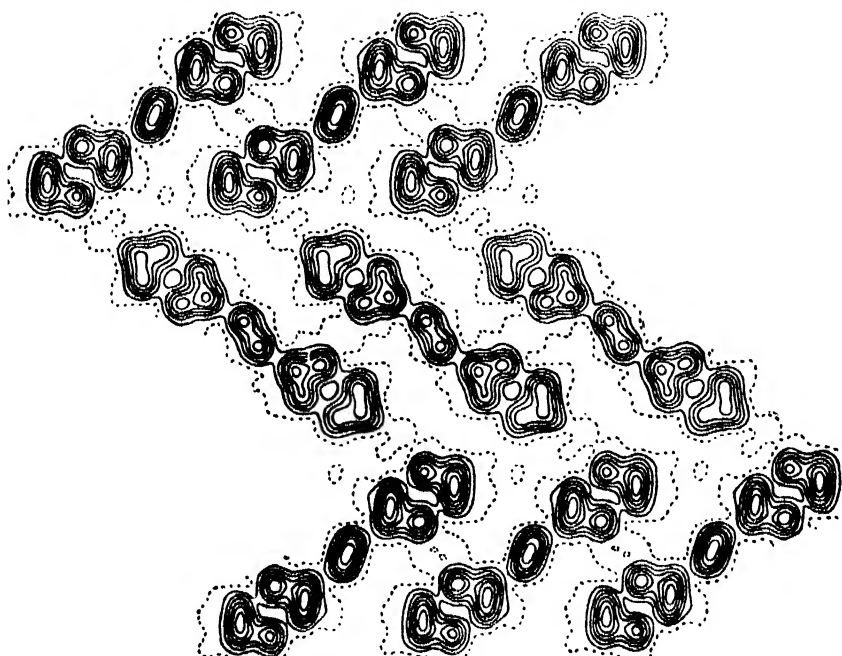


FIG. 4.—Stilbene.

Figs. 1-4 show the projections obtained by the use of double Fourier series in the case of durene $C_6H_4(CH_3)_4$, naphthalene $C_{10}H_8$, dibenzyl $C_6H_5CH_2CH_2C_6H_5$, and stilbene $C_6H_5CH=CHC_6H_5$. In each case the electron density is calculated by summing the double

series at many points taken close together on the projections, and the results are shown by drawing contour lines to pass through points of equal electron density. The first contour line is dotted and represents a density of approximately one electron per square Angstrom unit, and the other lines are drawn at unit intervals. The highest peaks therefore represent densities of 6 or 7 electrons per \AA^2 . The groups of molecules are drawn to show their relative orientation. The structures are, of course, continued indefinitely in a similar way in all directions.

In durene (Fig. 1) there is no difficulty in identifying the six carbon atoms that form the benzene ring, and the four symmetrically attached methyl groups. (Individual hydrogen atoms do not appear on the maps as their scattering power for X-rays is too small.) The complete structure of this crystal and the others shown were worked out by studying other zones of reflections and other projections at right angles to these. It was then found that all the atoms in the durene and naphthalene molecules lie quite accurately in one plane, but that this molecular plane is inclined at a large angle (about 50° in durene, and about 60° in naphthalene) to the plane of the projection given in these diagrams. As a result some of the atoms, for example, the end pairs in the naphthalene molecule, are so close together in the projections that they are not separately resolved but coalesce to form oval concentrations of density. The positions of the centres, however, can still be estimated with considerable accuracy. The actual maps from which the measurements are made are prepared from the Fourier summation totals by graphical interpolation methods on a scale about 15 times that used in these reproductions.

The complete structures show that the benzene rings are fairly accurate regular plane hexagons, the distance between the carbon atoms being about 1.41 A. in naphthalene, and perhaps slightly less in durene. The methyl groups are attached to the benzene ring in durene at the slightly greater distance of 1.47 A. Another point of interest is the comparatively large gap which separates the atoms in adjoining molecules, the distance between nearest neighbours varying from 3.6 to about 3.9 A. in the different crystals. These distances indicate very weak residual intermolecular forces. The molecules are loosely bound together, and the crystals are soft and flakey.

In dibenzyl (Fig. 3) the atoms of the molecule are no longer all in one plane. The benzene rings at each end of the molecule are regular hexagons as before, inclined at steep angles to the plane of the projection. The planes of these benzene rings, however, are

at different levels in the molecule and are found to lie almost at right angles to the plane containing the central CH_2CH_2 zig-zag, an arrangement which will be clear from Fig. 5. This is the con-

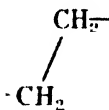
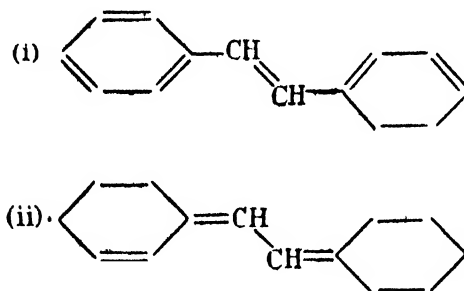


FIG. 5.—Dibenzyl.

figuration of the molecule when it is packed into the crystal. It cannot be predicted from the chemical formula, because free rotation is postulated about the single bonds of the central group. The three-dimensional configuration probably represents a compact structure of low potential energy which is accordingly utilised in building up the crystal.

In stilbene [16] on the other hand (Fig. 4), the structure of the molecule is very different. The over-all dimensions are rather similar to those of dibenzyl, and indeed the two crystals are almost isomorphous, except that in stilbene one of the axes has doubled in length. There are twice as many molecules in the unit of pattern, and the second layer is folded over on the first, as shown in the diagram. The appearance of the molecules in the two layers is slightly different in the projection, but it can be shown that this is not due to any inherent difference in shape between the two molecules but merely a result of the slightly different orientations which they assume with respect to the crystal axes. When the structures are fully worked out it is found that in contrast to dibenzyl the stilbene molecule is flat. All the atoms, both in the rings and the central group, lie in one plane, at least to within fairly narrow limits of experimental error. This flatness of the stilbene molecule, demonstrated by X-ray analysis, may be accounted for in a rather interesting way. The structural formula for stilbene (i) shows that there is a double bond between the central carbon atoms, which will, of course, prevent rotation taking place about this junction. But the bonds between the ethylene groups and the benzene rings are single bonds, so that the molecule might well assume the same shape as the dibenzyl molecule. In fact, the three-dimensional form of Fig. 5 would give considerably greater clearance between the ethylene hydrogen atoms and the ortho-hydrogen atoms of the ring. The central double bond in stilbene, however, is "conjugated" to the benzene ring, and modern theoretical and experimental work [12] shows that in such a case we must take account of an alternative excited structure, represented

by (ii), which may make a contribution to the normal state of the molecule. Now it is easily shown on general stereo-chemical grounds that (ii) can only contribute to the structure if the molecule is



planar. The fact that we find the stilbene molecule to be planar, in contrast to dibenzyl, is therefore very direct evidence that (ii) plays a part in the structure of the molecule.

Further quantitative evidence of the extent of this resonance between the alternative structures is obtained from the inter-atomic distances. The "single bonds" between the CH groups and the benzene rings are only about 1.45 Å. in length, comparing with the normal single bond value of 1.54 Å. in diamond. The double bond has a length of only about 1.32 Å., but this is not easy to measure accurately, and the figures may be subject to an error of about 0.04 Å.

We now pass on to consider the structure of some organic compounds containing oxygen, particularly those with a hydroxyl group. The X-ray analysis is often difficult, and not many structures of this kind have been accurately determined. The results obtained, however, provide some interesting information about the properties of these compounds.

Oxalic acid crystallises with two molecules of water, and the structure of this crystal has been completely determined by X-ray methods [19, 17]. The Fourier projection along the *b* crystal axis is shown in Fig. 6, accompanied by a diagram to show how the atoms are arranged. The acid molecule is seen to be surrounded by water molecules at distances of 2.5–2.8 Å. The positions of the atoms above and below the plane of the paper can be determined from another projection, and when the complete structure is worked out, the dimensions shown in Fig. 7 are obtained for the acid molecule. The six atoms all lie in one plane, but this plane is inclined at an angle of about 29° to the plane of the projection in Fig. 6.

The explanation of the planar form of the molecule is somewhat similar to that given for stilbene. Rotation about the C–C

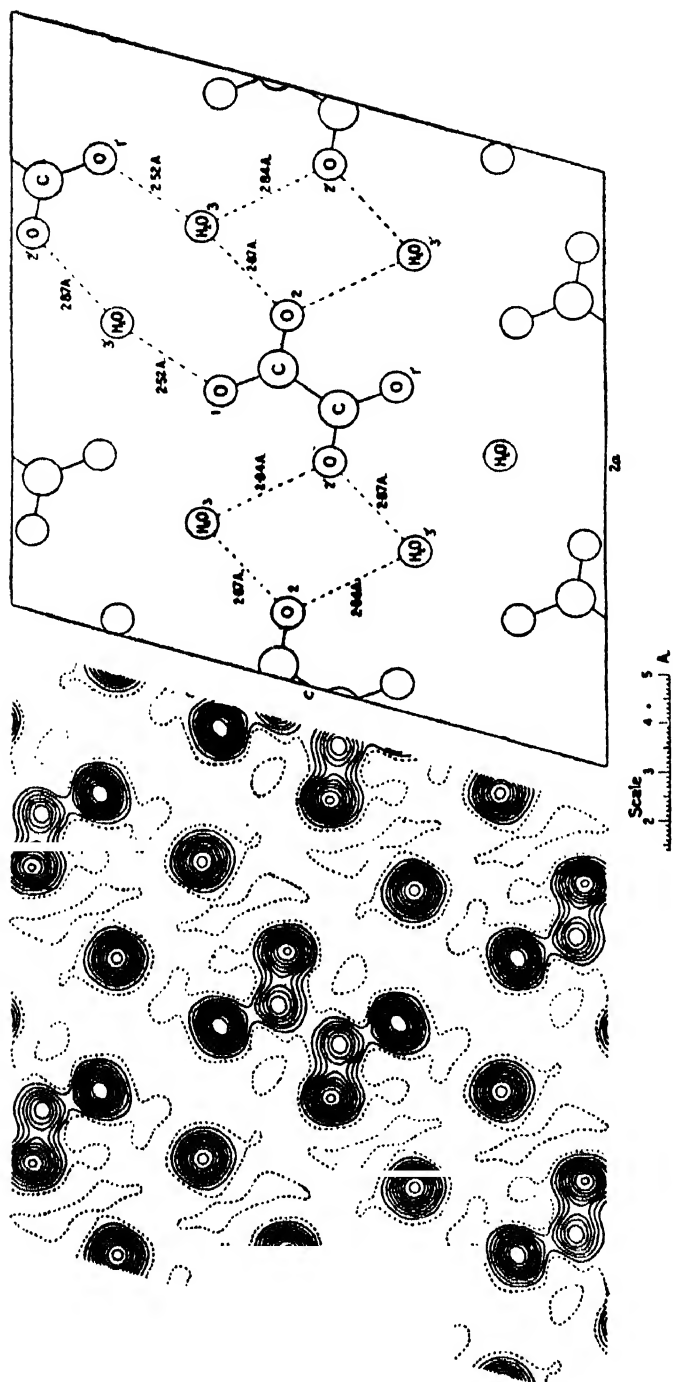


FIG. 6.—Oxalic acid dihydrate.

(reproduced by permission of the Chemical Society.)

bond in oxalic acid is evidently restricted by the conjugation of the double bonds in the end carboxyl groups. This is confirmed

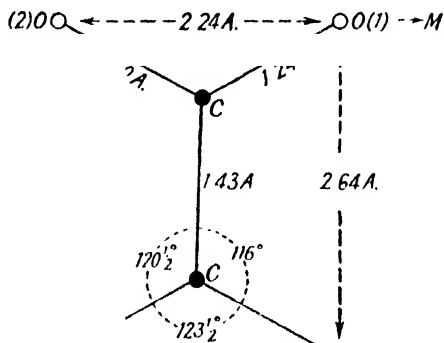


FIG. 7.—Dimensions of oxalic acid molecule.

by the length of the C-C bond which is only 1.43 Å. In fact, it is not a pure single bond at all, but must contain about 30 per cent. of double-bond property. This at once explains why the acid can be oxidised quantitatively with potassium permanganate, while in

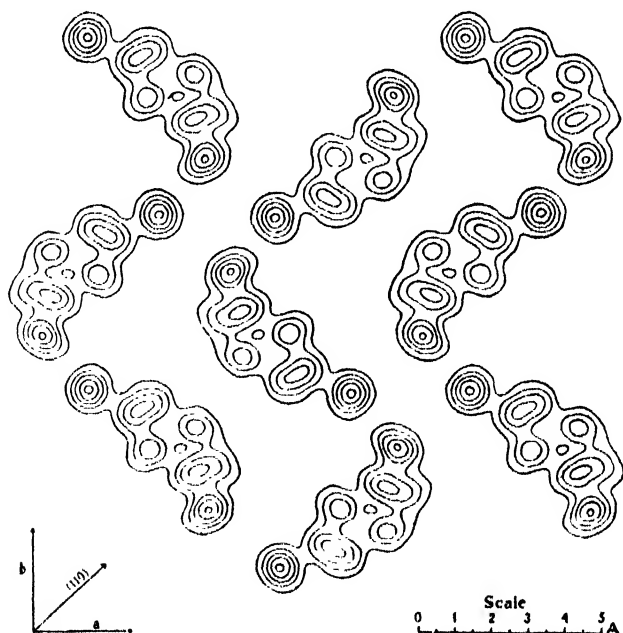
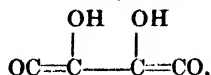


FIG. 8.—Resorcinol.

other compounds a carboxylic acid is usually the end product of such an oxidation.

In this connection reference may be made to recent theoretical work by Lennard-Jones [7] and Penney [14]. They predict that the length of the central bond in butadiene, $\text{CH}_2=\text{CH}-\text{CH}=\text{CH}_2$, should be only 1.43 Å. The situation is evidently somewhat similar to that in oxalic acid, which may be written



and the agreement is satisfactory.

With regard to the situation of the water molecules and the close intermolecular approach of 2.5–2.8 Å., it appears that such distances are characteristic of compounds containing OH groups. Two other examples may be given. The arrangement of resorcinol molecules in the crystal is shown in Fig. 8, projected along the *c* crystal axis. (In this contoured diagram each line represents a density increment of 2 electrons per Å².) The benzene rings are again regular plane hexagons, inclined at about 61° to the plane of the projection, and the OH groups in the meta positions are situated at 1.36 Å. from the aromatic carbon atoms. The oxygen atoms are seen to be directed towards each other in groups of four,

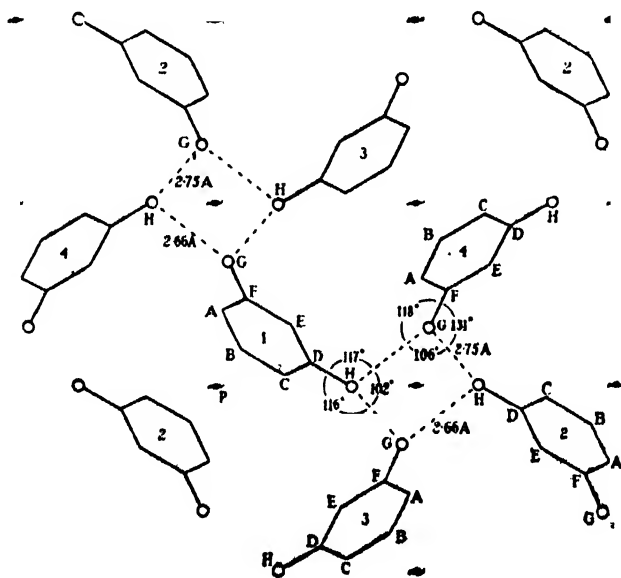


FIG. 8.—Resorcinol.
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and approach to within distances of about 2.7 Å. The complete structure shows that these molecules are at different levels in the crystal, and that the dotted lines joining the OH groups on the right actually form spirals extending through the crystal.

The structure of pentaerythritol, $C(CH_2OH)_4$, recently determined by Llewellyn, Cox, and Goodwin [9], is rather similar. This is an aliphatic alcohol, and the distances between the OH groups and the carbon atom are now found to be 1.46 Å., in contrast to 1.36 Å. which is characteristic of the phenols. The arrangement of the molecules in the crystal is shown in projection in Fig. 9, and we see that the grouping of the oxygen atoms is very similar to that of resorcinol, the approach distance being 2.69 Å. The molecules shown are all at the same level, however, and are connected through the OH groups to form sheets in the crystal, instead of spirals as in the case of resorcinol.

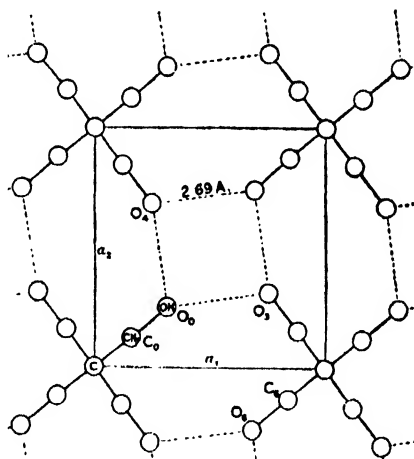


FIG. 9.—Pentaerythritol.

(Reprinted by permission of the Chemical Society.)

We see, therefore, that minimum intermolecular distances of from 2.5 to 2.8 Å. appear to be characteristic of hydroxylic compounds. These distances indicate intermolecular attractions of considerably greater strength than we found in the case of the hydrocarbons, and corresponding to this fact the crystals of all these oxygen compounds are relatively hard and brittle compared with the soft and flakey hydrocarbon crystals. Molecular association of hydroxylic compounds is well known in chemistry, and the physical explanation in terms of hydrogen and hydroxyl bonds has received a great deal of attention recently [2]. Precise measure-

ments of interatomic distance are of the greatest importance in clarifying such work.

In the structures so far described, with the exception of pentaerythritol, recourse was always necessary in the preliminary stages of the X-ray analyses to information about the relative positions of the atoms obtained by chemical methods. Although the final X-ray results are quite independent of the precise details of these initial assumptions, yet the situation is to some extent unsatisfactory, and the results would be made much more convincing if they could be determined in a really direct manner from the X-ray data without the necessity for intermediate assumptions. It is a matter of considerable interest, therefore, to note that this has recently been achieved for certain organic structures.

We have seen that the essential difficulty of the X-ray method arises from the ambiguity involved in the unknown phase constant of each reflection. One method of partially overcoming this difficulty has recently been devised by Patterson [11] and improved by Harker [4]. We cannot give details of the method here, but the essential feature lies in the use of a different kind of Fourier series, in which the coefficients are squared and become independent of the sign or phase constant. The three-dimensional function expressed by this series does not tell us the positions of the atoms in the crystal, but maxima occur at points which, with reference to the origin, give the vector distances between pairs of atoms in the structure. There remains the ambiguity of deciding to what pairs of atoms in the structure these vectors refer. When many atoms are present the results are very confusing, but with simple structures the method can often be applied with considerable success, especially when advantage is taken of the symmetry properties of the crystal to simplify the numerical calculations.

The pentaerythritol structure described above was obtained by an application of this method, and it was consequently unnecessary to make use of the known chemical configuration of the molecule. The co-ordinates of the atoms with reference to the crystal axes were deduced in a direct manner, which, however, was not entirely free from possible ambiguities. For details, reference must be made to the original paper [9].

It is a somewhat surprising fact that the most direct of all the X-ray determinations of organic structures have recently been made on a series of extremely complex compounds, known as the phthalocyanines [8, 15, 17], which contain 32 carbon and 8 nitrogen atoms in the molecule. The electron density map for one of these molecules is shown in Fig. 10, and the point of particular interest here

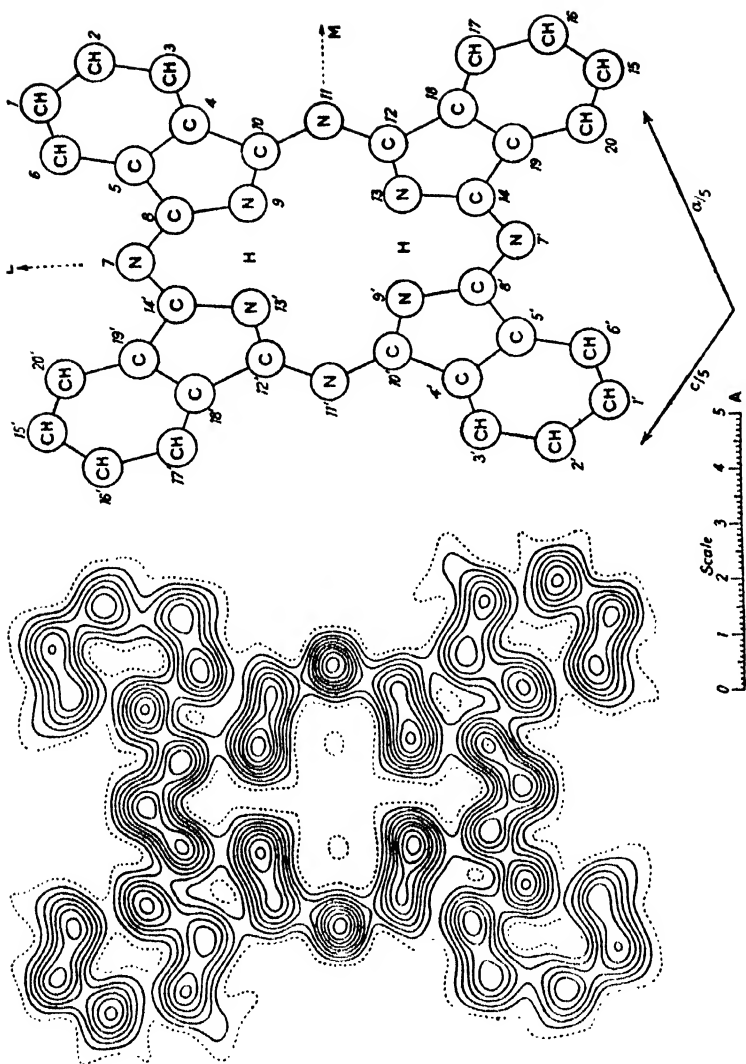


Fig. 10.—Projection along the b axis, showing one complete phthalocyanine molecule. The plane of the molecule is steeply inclined to the plane of the projection, the M direction making an angle of 46° with the b axis, and the L direction 2.3° . Each contour line represents a density increment of one electron per \AA^2 , the one-electron line being dotted. (Reprinted by permission of the Chemical Society.)

lies in the fact that this map was obtained directly from the X-ray results without assuming the existence of separate atoms in the molecule at all. The well-defined benzene rings at the corners of the large molecule, and the other groups of carbon and nitrogen atoms, are thus an excellent confirmation of all the previous results. Unfortunately, the method of analysis employed cannot be applied very generally as it requires two special features—an isomorphous series of crystalline compounds, with a replaceable atom on a symmetry element.

We have seen that each X-ray reflection is the resultant of the contributions scattered by all the electrons in the unit of structure, and the main problem is to determine the phase constant of this resultant wave. If the structure has a centre of symmetry, then this wave must have either a peak or a trough at the centre of symmetry. Now if one of the scattering particles in the structure is situated exactly at the centre of symmetry, its contribution to the resultant wave will always be a maximum, and will correspond to a small wave with a peak at the centre of symmetry. Similarly, a single atom at the centre of symmetry gives a contribution to the resultant reflection which is always a peak, at least for all planes down to those with spacings small compared to the size of the atom. The contribution from all the rest of the molecule may correspond either to a peak or a trough at the symmetry centre, and we have to determine which.

In free phthalocyanine (Fig. 10) there is no atom at the centre of symmetry (centre of the molecule), but isomorphous derivatives can be prepared containing a metal atom in this position. That the metal atom enters the structure at this point can be proved directly by X-ray methods. We then note the intensity of the X-ray reflection from a given plane in the free compound, and from the same plane in the compound containing the metal atom. If the intensity is greater for the metal compound, we know that the reflection from the free compound must correspond to a wave with a peak at the symmetry centre, which has been increased in amplitude by the addition of the small peak due to the metal atom alone. If, however, the intensity is less for the metal compound, we can infer that the original wave must have had a trough at the symmetry centre, which has been partially filled up by the peak due to the metal atom, with a consequent decrease in total amplitude. When absolute measurements are employed, there is no ambiguity for all the measurable reflections, and the phase constants can be determined directly in this simple manner. A straightforward Fourier synthesis can then be carried out.

peculiar structure of this inner nucleus. A very similar nucleus, but with the four outer nitrogen atoms replaced by CH groups, is the basis of the porphyrins, an extremely important class of natural organic colouring matters, which includes chlorophyll, haemin, and many other animal and plant products.

Amongst the other organic compounds containing nitrogen whose structures have been fully ascertained by X-ray analysis are urea, $C:O(NH_2)_2$, by Wyckoff [18] and cyanuric triazide, $C_3N_3(N_3)_3$, by I. E. Knaggs [6]. The latter compound, which is a violent explosive, consists of a six-membered ring of alternate carbon and nitrogen atoms with three azide groups attached. The X-ray analysis of the structure is of particular interest because it demonstrates clearly that the azide group has a linear structure, and not a ring structure as had been thought possible.

REFERENCES

1. BERNAL, J. D., and CROWFOOT, D., *J. chem. Soc.*, 93 (1935).
2. BERNAL, J. D., and MEGAW, H. D., *Proc. roy. Soc., A*, **151**, 384 (1935).
3. BRAGG, W. H., *Phil. Trans. roy. Soc., A*, **215**, 253 (1915).
4. HARKER, D., *J. chem. Phys.*, **4**, 381 (1936).
5. IBALL, J., *Z. Kristallogr.*, **92**, 293 (1935); **93**, 47; **94**, 7, 397; **95**, 282 (1936).
6. KNAGGS, I. E., *Proc. roy. Soc., A*, **150**, 576 (1935).
7. LENNARD-JONES, J. E., *Proc. roy. Soc., A*, **158**, 280, 297 (1937).
8. LINSTAD, R. P., *J. chem. Soc.*, 1016 (1934).
9. LLEWELLYN, F. J., COX, E. G., and GOODWIN, T. H., *J. chem. Soc.*, 883 (1937).
10. LONSDALE, K., *Proc. roy. Soc., A*, **123**, 494 (1929).
11. PATTERSON, A. L., *Z. Kristallogr.*, **90**, 517 (1935).
12. PAULING, L., and SHERMAN, J., *J. chem. Phys.*, **1**, 806 (1933).
13. PAULING, L., and WILSON, E. B., *Introduction to Quantum Mechanics*, McGraw-Hill Book Co. Inc., New York and London.
14. PENNEY, W. G., *Proc. roy. Soc., A*, **158**, 306 (1937).
15. ROBERTSON, J. M., *Proc. roy. Soc., A*, **142**, 659, 674 (1933); **150**, 348 (1935); **157**, 79 (1936); *J. chem. Soc.*, 615 (1935); 1195 (1936).
16. ROBERTSON, J. M., PRASAD, M., and WOODWARD, I., *Proc. roy. Soc., A*, **154**, 187 (1936).
17. ROBERTSON, J. M., and WOODWARD, I., *J. chem. Soc.*, 1817 (1936); 219 (1937).
18. WYCKOFF, R. W. G., *Z. Kristallogr.*, **81**, 102 (1932).
19. ZACHARIASEN, W. H., *Z. Kristallogr.*, **89**, 442 (1934).

THE STRUCTURE OF THE UNIVERSE

By G. C. MCVITTIE, M.A., PH.D., F.R.A.S.

Reader in Mathematics in the University of London, King's College

DURING the present year the Mount Wilson Observatory has published the result of observations on the number of extra-galactic nebulae visible with the great 60-inch and 100-inch telescopes. These observations have enabled astronomers, for the first time, to calculate with some degree of accuracy the general features of the structure of the universe. At the same time the researches of Sir Arthur Eddington on the relationship of the quantum theory and general relativity have also shed light on the cosmical problem. In a quite different field, Professor E. A. Milne has continued his development of the kinematic theory of the universe. The present moment therefore appears to be an opportune one to review our knowledge of this subject.

THE RECESSION FORMULA.—For a dozen years or more, evidence has accumulated in favour of the “recession” of the extra-galactic nebulae. This term, with its suggestion of movement, is perhaps a little unfortunate. What is actually observed is a displacement towards the red of all lines in the spectrum of a nebula, this displacement depending on the apparent magnitude, *i.e.* on the observed brightness, of the nebula. In fact, if $\delta = \frac{d\lambda}{\lambda}$ denote the fractional displacement in light of wave-length λ , and m is the apparent magnitude of the nebula emitting the light, it is found that

$$\log_{10} \delta = 0.2m - 4.967. \quad . \quad . \quad . \quad . \quad . \quad (1)$$

This formula can, however, be turned into a velocity-distance relation by making the following assumptions. Firstly, we assume that space is the ordinary Euclidean space of physics; secondly, that the laws of light-propagation are those of classical electromagnetic theory and thirdly, that the red-shift is a Doppler effect due to a velocity of recession V where

$$\frac{V}{c} = \delta. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

The first two assumptions yield the formula

$$\log_{10} D = 0.2(m - M) + 1, \quad . \quad . \quad . \quad (3)$$

D being the distance in parsecs¹ and M the absolute magnitude of a nebula of apparent magnitude m . By absolute magnitude is meant the magnitude the nebula would have if it were placed at the standard distance of 10 parsecs from the sun. Equations (1), (2) and (3), together yield

$$V = c10^{0.2M-5.967} D, \quad . \quad . \quad . \quad (4)$$

There are reasons for believing that the absolute magnitude of all nebulae is statistically constant and of amount -14.2 . Inserting this value of M into (4), the value of V is, in round numbers, 500 km./sec. per 10^6 parsecs.

It should be noticed that the formula (3) is merely a definition of what we mean by the distance of a spiral nebula in terms of its apparent magnitude. No independent determinations of D and m exist for any nebula by which the validity of (3) could be checked.

We have not yet excluded the possibility that our observations summarised in (1) may be due to our occupying some peculiar position in the universe. The expanding universe theory of general relativity assures us that this will not be the case provided that the metric of the universe² is

$$ds^2 = dt^2 - \frac{R^2(t) dr^2 + r^2 d\theta^2 + r^2 \sin^2 \theta d\varphi^2}{c^2 (1 + kr^2/4)^2}, \quad . \quad . \quad (5)$$

In this expression, $R(t)$ is a real function of t called the *radius of curvature of space*, the nature of the curvature being determined by the constant k whose values may be $+1$, 0 or -1 . Moreover, small regions of the space-time (5) are approximately Euclidean so that the three assumptions underlying (4) hold good. The latter formula then leads to

$$\frac{\dot{R}}{R} = 2 \times 10^{-17} \text{ sec.}^{-1}, \quad . \quad . \quad . \quad (6)$$

¹ 1 parsec = 3.258 light-years = 1.92×10^{13} miles.

² If an event takes place at a spatial position specified by the co-ordinates r, θ, φ and at a time specified by t , and if the event with co-ordinates $r + dr, \theta + d\theta, \varphi + d\varphi, t + dt$ is any neighbouring event, then the quantity ds calculated by a formula such as (5), is termed the *interval* between the two events. It is a combination of the concepts of the distance and of the lapse of time between them. The formula (5) itself, giving ds as a function of the co-ordinate-increments $dt, dr, d\theta, d\varphi$, is called the *metric*. When one and the same formula may be used to calculate the interval between any pair of neighbouring events in the universe, this formula constitutes the metric of the universe.

where \dot{R} is the present time-rate of change of the radius. This relation is the sole contribution made by the recession formula to the determination of the metric (5) and therefore to the solution of the problem of the structure of the universe. But even this contribution can be questioned. It was pointed out by E. A. Milne that, still excluding the possibility of our occupying some unique position in the universe, the hypothesis of curved space embodied in the use of (5) was unnecessary for the interpretation of (1). In fact, if we are content to abandon the principles of general relativity, the recession formula is found to be compatible with motion in ordinary space.

This was the somewhat unsatisfactory state of affairs up to the time of the publication of the Mount Wilson "nebular-count" observations.

NEBULAR COUNTS.—In addition to the recession formula, both the theory of general relativity and Milne's kinematic theory predict certain laws governing the distribution of nebulae in space. The object of the determinations of the number of nebulae carried out at the Harvard College Observatory under Shapley and chiefly at the Mount Wilson Observatory under Hubble has been to find the distribution actually existing in the universe [1]. In principle, the procedure adopted is to count on photographs of definite regions of the sky all the nebulae with apparent magnitudes not fainter than each of a series of magnitude values. In the most extensive count the magnitudes were +18.47, 19, 19.4, 20 and 21.03. In practice, this procedure is complicated by, amongst other causes, the actual unevenness of the distribution of the nebulae. A strong tendency to form clusters is observed, some of these having hundreds or even thousands of members. Again our own Galaxy, like so many other spiral nebulae, contains clouds of dark obscuring material. Especially is this the case in its equatorial plane, the region of the Milky Way. In this part of the sky there are practically no extra-galactic nebulae visible, such faint objects being completely invisible through the dark clouds. The counts have therefore to be made on photographs of those regions of the sky which are considered to contain a normal distribution of nebulae and the results extrapolated to the whole sky. In addition, there are purely technical corrections to be applied for the effects of the earth's atmosphere, for the quality of the photographic images of the nebulae, for the times of exposure, etc. If, finally, we denote by N the number of nebulae of apparent magnitude less than or equal to m , the empirical formula between these two quantities, for counts carried down to $m = 20$, is

$$\log_{10} N = 0.6m - 4.71. \quad . \quad . \quad . \quad . \quad (7)$$

When, however, the counts are carried to $m = 21.03$ the relation is

$$\log_{10} N = 0.501m - 2.758. \quad . \quad . \quad . \quad . \quad (8)$$

The latter formula is believed to be the best that can be obtained with present-day telescopes: any significant revision must await the completion of the 200-inch telescope.

INTERPRETATION OF THE NEBULAR COUNTS.—The two foregoing formulæ give us N only as a function of apparent magnitude m . Their theoretical interpretation, aiming at showing that they correspond to the distribution of nebulae in some particular universe of the class (5), has proved a matter of some difficulty and has led to a certain amount of controversy.

The first method of comparison between theory and observation is due to Hubble and Tolman [2]. They argue on the pre-supposition that the curvature of space must be so small that all visible nebulae may be regarded as moving in an ordinary Euclidean space. Since the spectrum of a nebula is displaced towards the red it must appear fainter, and therefore more distant, than in fact it is. The nebular-count formulæ should therefore be corrected to allow for this effect and to reduce them to the "true" distances of the nebulae. When Hubble applied this method to formula (7) satisfactory results were obtained. The radius of curvature of the universe was deduced to be so large that the assumption of an approximately Euclidean space was justified and the value of the constant k in (5) was indeterminate. The average density of matter in the universe was of the order of 10^{-30} gr./cm.³, assuming that the average mass of a nebula was 10^9 times that of the Sun. But when the same analysis was used on formula (8), which presumably refers to greater depths of space, very different and unexpected results were obtained. The metric of the universe (5) now had

$$k = +1, R = 1.4 \times 10^8 \text{ parsecs}, \quad . \quad . \quad . \quad . \quad (9)$$

whilst the average density of matter in space was found to have the very high value of 10^{-26} gr./cm.³. The positive value of k signifies that space at any moment is spherical and therefore of finite extent. Moreover, the radius is so small that present-day telescopes must be capable of exploring the greater part of space.

Such discrepancies are probably unavoidable in a treatment which aims at arriving at the "true" distance-distribution of the nebulae. In cosmological theory the concept of distance is ambiguous, its meaning depending on the method of distance-measurement adopted. With regard to the details of the treatment, the correction to the apparent magnitude of a nebula, arrived at by

manipulation of formulæ (1) and (8), has an "empirical" value

$$\Delta m = 2.94\delta, \quad . \quad . \quad . \quad . \quad . \quad (10)$$

where δ is the Doppler shift corresponding to apparent magnitude m . The theoretical formula is found to be

$$\Delta m = 4\delta \quad . \quad . \quad . \quad . \quad . \quad (11)$$

and the discrepancy between (10) and (11) is attributed to the effects of the curvature of space and leads to the small closed universe (9). In order, however, to arrive at this result, the distribution of energy in the spectrum of an average nebula must be known. Hubble takes it to be that of black-body radiation of temperature 6000° . The value of Δm appears to depend very largely on this assumption, for if 7500° is used in the calculations instead of 6000° , (11) is replaced by

$$\Delta m = 3\delta.$$

Since this formula is practically identical with (10), there is now presumably no need to appeal to curvature of space in order to obtain agreement between observation and theory. In short, Hubble makes the curvature depend on the character of the radiation emitted by the nebulae, a conclusion difficult to reconcile with the principles of general relativity which assert that the curvature of space depends only on the masses and the distribution of the nebulae.

HYPERBOLIC SPACE.—A small correction such as Δm is necessarily dependent on many factors difficult to disentangle from one another. To avoid comparing observation and theory via Δm it would be desirable to use the complete formulæ (7) and (8) themselves. Moreover, considerations of distance are to be avoided if possible, owing to the ambiguity of this term. The closest approach to such an ideal treatment is probably obtained as follows. Eliminating m from (1) and either of (7) or (8), an expression for $dN/d\delta$ in terms of δ is obtained which gives the rate of increase in the number of nebulae with Doppler shift. The arbitrary element in this procedure is the assumption that (1), which has been established observationally for nebulae not fainter than $m = 17$, continues to hold down to $m = 21.03$. The next step is to calculate for a universe with metric (5), the theoretical value of $dN/d\delta$. This is found to be a series in powers of δ , the coefficients of which involve the values of the radius $R(t)$ and its successive time-derivatives. A comparison of the theoretical and empirical formulæ for $dN/d\delta$ then yields the following results [4]:—(i) if (1) and (7) are combined, the metric of the universe (5) is such that

$$k = -1, R > 11 \times 10^8 \text{ parsecs}, \quad . \quad . \quad . \quad (12)$$

whilst, with a nebular mass of 10^9 times that of the Sun, the average density of matter in space is 2.2×10^{-30} gr./cm.³; (ii) when (1) and (8) are used, there is obtained

$$k \dots -1, R = 3.5 \times 10^8 \text{ parsecs,} \quad . \quad . \quad . \quad (13)$$

with an average density of amount 3.4×10^{-30} gr./cm.³. Admittedly the two nebular-count formulæ still give somewhat different results but there is now much better agreement than there was in the Hubble-Tolman treatment. It is also interesting to note that the density of matter is of the same order of magnitude as that found by Shapley from the Harvard counts [3] of nebulae brighter than the thirteenth magnitude.

The significance of the negative value of k in (12) and (13) is that it indicates the *hyperbolic* character of space. By this is meant that space at any moment is infinite in extent but that it, nevertheless, possesses curvature. The amount of the curvature is approximately the same as that of the Hubble-Tolman small closed universe (9). In fact, the difference between the spherical universe (9) and the hyperbolic universes (12) and (13) is in some ways analogous to the difference between the circle $x^2 + y^2 = r^2$ and the corresponding rectangular hyperbola $x^2 - y^2 = r^2$. In the former curve, the curvature is such that the circumference closes in upon itself producing a curve of finite length: in the latter, the curvature has the opposite effect so that a curve of infinite length is obtained.

In conclusion, it may be said that the actual universe is probably an infinite hyperbolic universe with a radius of curvature of some 10^8 parsecs and that it contains matter of average density 10^{-30} gr./cm.³.

KINEMATICAL THEORY.—An alternative theory of the universe is provided by E. A. Milne's kinematical relativity [5]. This theory discards the principles of general relativity and, in particular, the notion that the curvature of space is intrinsically associated with the properties of the material content of space. The nebulae are therefore assumed to be moving with constant relative velocities in the Euclidean space-time of special relativity whose metric is

$$ds^2 = dt^2 - \frac{1}{c^2} \{dx^2 + dy^2 + dz^2\}.$$

If we imagine that an observer is associated with each nebula, the co-ordinate systems used by these observers must be connected by the formulæ of the Lorentz transformation. We have already remarked that this theory will account for the velocity-distance

relation (1). It remains to be seen whether it will also account for the nebular-count formulæ.

Kinematical relativity predicts the following formula for $dN/d\delta$, viz.—

$$\frac{dN}{d\delta} = \pi\alpha\delta^2 \frac{(2 + \delta)^2}{(1 + \delta)^3} = 4\pi\alpha(\delta^2 - 2\delta^3 + 3.25\delta^4 - \dots), \quad (14)$$

where α is a constant giving the density of nebulae in space. The corresponding empirical formula obtained from (1) and (8), and from which (13) is derived, is

$$\frac{dN}{d\delta} = 7.12 \times 10^{10}(\delta^2 - 6.41\delta^3 + 12.1\delta^4 + \dots). \quad (15)$$

This case is selected for discussion since it refers to the greatest depths of space observable to-day. By a suitable choice of the constant α , (14) and (15) can be made to agree as far as their terms in δ^2 are concerned. But it is evident that agreement beyond this first approximation is not possible. Nor is it legitimate to overcome this difficulty by simply neglecting the terms in δ^3 , δ^4 , etc. For, calculating δ at $m = 21.03$ from (1), its value is $\delta = .17$ so that the higher order terms contribute sensibly to the value of $dN/d\delta$ at these great depths of space. Thus Milne's theory agrees with the nebular counts up to the first approximation only. Even if future observations should substantially alter (15) it seems quite outside the bounds of probability that the particular function (14) will be obtained. There is, however, a way of escape. It consists in abandoning Milne's hypothesis that the nebulae are moving in the Euclidean space-time of special relativity and in reconstructing his theory in curved space-time. Milne's form of the theory then plays the part of a first approximation and a suitable choice of curvature now so modifies (14) that agreement with (15) can be obtained. In particular, kinematical relativity constructed in the universe whose metric¹ is

$$ds^2 = \frac{dt^2 - (dx^2 + dy^2 + dz^2)/c^2}{[1 - K^2(c^2t^2 - x^2 - y^2 - z^2)]^2} \quad (16)$$

will secure agreement with (15) up to the term in δ^3 . It is to be noted that curvature now enters the theory of the universe as a consequence of the distribution of the nebulae alone and does not depend, as it did in general relativity, on the masses of these bodies as well.

But such a modification of kinematical relativity would probably

¹ K is a constant depending on the amount of the curvature. Its physical dimensions are those of $(\text{length})^{-1}$.

be regarded with disfavour by Milne himself. The reason for this is that the introduction of a universal curvature constant contradicts a principle of which he makes much use. This may be stated as follows:—"The mathematical description of the universe must not involve any universal constant of the dimensions of length or of time." Milne has developed an elaborate theory of gravitation on the basis of this hypothesis. His equation for gravitational acceleration, valid in the space-time of special relativity, is

$$\frac{d^2x}{dt^2} = \left(x - t \frac{dx}{dt}\right) \frac{Y}{X} G(\xi) \quad . \quad . \quad . \quad (17)$$

with similar equations for y and z . In (17)

$$Y = 1 - \frac{1}{c^2} \left\{ \left(\frac{dx}{dt}\right)^2 + \left(\frac{dy}{dt}\right)^2 + \left(\frac{dz}{dt}\right)^2 \right\}, \quad X = t^2 - \frac{1}{c^2}(x^2 + y^2 + z^2),$$

$$Z = t - \frac{1}{c^2} \left(x \frac{dx}{dt} + y \frac{dy}{dt} + z \frac{dz}{dt} \right), \quad \xi = Z^2/YX$$

and G is an arbitrary function depending on the distribution of matter in the universe. In the first instance, (17) is arrived at on the ground that the acceleration formula must be invariant under Lorentz transformations. This determines G to be a function of the two invariants X/T_0 and Z^2/YT_1 , where T_0 and T_1 are universal constants of dimensions (time)⁺². Using the principle already mentioned, Milne restricts G to be a function of the dimensionless argument ξ alone. If, however, the distribution of nebulae necessitates the introduction of universal constants, there is no longer any reason for excluding them from the equation of gravitational acceleration. Milne's theory of gravitation must therefore be regarded as one possibility only selected from the group of gravitational theories provided by kinematical relativity.

GENERAL RELATIVITY AND QUANTUM THEORY.—The astronomical observations do not therefore lead to a unique solution of the problem of the structure of the universe. In one way this is to be expected because the recession and the distribution of the nebulae provide but two criteria by which any suggested theory of the universe could be tested. During the last nine years, however, Sir A. S. Eddington's researches [6] on the connection between the theory of general relativity and the quantum theory have, as one of their consequences, linked up cosmical with atomic phenomena. If Eddington's ideas are accepted, there emerges an additional test for any proposed scheme of structure for the universe.

It is well known that since 1900 Newtonian mechanics has developed along two mathematically distinct lines represented by

general relativity on the one hand and by quantum theory on the other. Eddington's achievement has consisted in the construction of a very general type of quantum mechanics which is in agreement with general relativity. Unfortunately, the alterations necessary in building up this unification have all been at the expense of the quantum theory, general relativity having emerged from the ordeal quite unaltered. In consequence, Eddington's quantum theory differs in a great many respects from the generally accepted form associated with the names of Heisenberg and Dirac. Indeed, in treating the problem of the equation of state of very dense matter, the two quantum theories lead to quite different results. Be this as it may, one of the products of Eddington's ideas is a value for the radius of curvature at the moment when the expansion of the universe began. This calculation may be summarised as follows. There is a particular case of (5), called the Einstein universe, in which

$$R(t) = \text{constant}, \quad k = +1.$$

General relativity predicts that a universe of this type can exist in an equilibrium state, neither expanding nor contracting but filled with motionless matter at constant density and containing no radiation. Moreover, the equilibrium of an Einstein universe is unstable: an appropriate disturbance will start it expanding and it will continue to do so indefinitely so that it is a tenable hypothesis that the actual universe began its expansion in this way. The condition of the Einstein universe is very similar to that of an atomic system in its fundamental state of lowest energy since in such a state the system is also static and radiationless. Eddington therefore argues that it should be possible, by means of the quantum theory, to build up an Einstein universe particle by particle, the whole final system of particles being in its fundamental state. This achievement is quite beyond the capacity of the ordinary quantum theory, but, by means of his generalised theory, Eddington accomplishes it after a very intricate mathematical argument. He then compares his solution with that already given by general relativity and finds for the metric (5) of the actual universe (i) that $k = +1$, so that space is spherical; (ii) that the radius had the initial value of 4×10^8 parsecs and that it has a very much greater value now; (iii) that the limiting speed of recession of the nebulae is 432 km./sec. per 10^6 parsec. The latter result is in striking agreement with the observational value.

If Eddington's theory is accepted, there is no need to appeal to nebular counts to determine the curvature of space. And the fact that these counts suggest either a hyperbolic universe in which

$k = -1$, or a spherical universe of very small size, merely indicates, in Eddington's opinion, the very great errors to which such observations must be liable.

CONCLUSION.—Summarising, we may say that the counts of spiral nebulae, when interpreted by general relativity alone, indicate a universe infinite in extent but nevertheless possessing a fairly high degree of curvature. If, on the other hand, the observations are to be interpreted on Milne's kinematical relativity, curvature must be introduced into this theory with consequent unfavourable repercussions on Milne's theory of gravitation. Lastly, adopting Eddington's unification of general relativity and quantum theory, the universe is found to be spherical, finite in extent but extremely large, and the nebular count formulæ are to be regarded as too unreliable to give trustworthy results. In contrast with the indefiniteness of our knowledge a year ago, we are therefore presented to-day with a small number of clear-cut solutions of the cosmical problem. Which of these, however, is to be deemed the correct one only further observational and theoretical researches can show.

REFERENCES

1. E. HUBBLE, *Astrophys. J.*, **79**, 8, 1934 ; **84**, 517, 1936.
2. E. HUBBLE and R. C. TOLMAN, *Astrophys. J.*, **82**, 302, 1935.
3. H. SHAPLEY, *Ann. Harv. Coll. Obs.*, **88**, No. 2, 1932.
4. G. C. McVITTIE, *Cosmological Theory*, Chap. IV, Methuen's Monographs on Physical Subjects, 1937.
5. E. A. MILNE, *Relativity, Gravitation and World-Structure*, Oxford Press, 1935.
—, *Proc. Roy. Soc., A*, **156**, 62, 1936 ; **158**, 324 ; **159**, 171 and 526 ; **160**, 1, 1937.
6. A. S. EDDINGTON, *Relativity Theory of Protons and Electrons*, Chap. XIV, C.U.P., 1936.

MANGANESE AND COBALT IN PLANT AND ANIMAL ECONOMY

By ETHEL BROWNING, M.D.

MANGANESE

It has long been recognised that manganese is not only of practically universal distribution in the plant world but that it is an essential factor in plant metabolism and growth. At what point and in what manner its action on the plant cells is exerted is even now not completely understood, but the idea advanced by Bertrand in 1897 [3] (and later rejected) that manganese was the true active principle of the oxidases, or ferments which control the oxygen metabolism of the plant, appears, with modifications, to have gained some ground during recent years. It has been demonstrated by several workers [25, 31, 67, etc.] that these oxidising enzymes all show increased activity when the plants are fertilised by manganese, but whether this increase is due to the action of manganese as a co-ferment or as a catalytic agent is still undecided.

There has been much more uncertainty and disagreement about the part played by manganese in the economy of the animal organism. It is a normal constituent, though in much smaller degree than in the case of plants, of practically all animal tissues. It has been found in blood [50], teeth [31], bile [68], gall-stones [68], milk [37], urine [54], and in most of the internal organs [9]. But whether its presence there is accidental, arising from the ingestion of foods which are very rarely free from manganese, or whether it is a necessary and indispensable constituent of the normal organism has been seriously questioned.

Even when it was decided that it had a favourable effect on the growth of young animals [27, 34, 36], efforts to explain the mechanism of its action were often unsuccessful, and not all workers were even able to decide whether its absence definitely had a bad effect on growth. Its "growth effect," if any, has been variously related to its stimulation of ovarian and testicular function [27]; to the production of a hormone, probably from the anterior lobe of the pituitary, which is essential for the proper functioning and

development of lactation [42]; to its effect in maintaining the normal development of young or embryonic tissue [20]; and to the alleged necessity of its presence for the adequate formation of hæmoglobin [59].

As in the case of plant tissues, however, scientific opinion appears to incline ultimately to the conception of manganese as a catalyst or activator of the vital enzymic reactions of the organism rather than as a specific stimulant of any tissue or group of tissues. One of the most recent modifications of this conception [23] postulates a delicate relationship between manganese and vitamin B₁, especially in regard to the known oxidative capacity of the latter.

MANGANESE IN PLANT TISSUES

While the actual amounts of manganese in plants are small in comparison with some other minerals—iron, for example, is on the average three times as abundant in most plant materials as manganese—and while it exhibits wide variations in different materials and species, it shows a concentration in those parts of the plant where reproductive activity is greatest [14]. Seeds in the process of ripening show a striking increase in their manganese content [53]; in cereals, the by-products, especially the germ, are much richer than the whole grain [38]; young leaves contain more manganese than older ones [15]; and in trees and flowers the reproductive parts have the highest content and the woody parts very little [14]. Among the most commonly used foodstuffs of vegetable origin, the highest manganese content is from 100 to 200 mgm. per kgm. (beet tops, blueberries, lettuce, pineapple, and wheat bran); another group contains 35 to 100 mgm. per kgm. (beets, blackberries, chard, oats, spinach, and whole wheat); while most fruits and a group of vegetables including carrots, onions, radishes, and turnip, contain less than 15 mgm. per kgm [26, 47, 51]. It is interesting, in view of a possible relationship between vitamin B₁ and manganese, to note that whole wheat, with a manganese content of 31 mgm. per kgm. is much lower in both manganese and vitamin B₁ than wheat embryo, which contains 390 mgm. per kgm. of manganese and is one of the richest known sources of vitamin B₁.

MANGANESE IN ANIMAL TISSUES

Animal tissues are on the whole lower in manganese content than vegetable tissues. Beef and fish (except molluscs, which are especially rich, owing, it is believed, to the high manganese content of the water in which they are found) contain very little [17]; milk, 0.003–0.004 mgm. per 100 c.c. [28, 37] (colostrum is considerably

higher) [53]; and blood 0.004 to 0.020 mgm. per 100 gm. [50]. In eggs the yolk only appears to contain manganese and its content increases during maturation of the ovaries of the hen [9].

In view of the belief that manganese is an inevitable constituent of the body, it is worthy of note that the individual level of the blood is constant with repeated examinations and is not increased by exposure to the dust of manganese ores [50].

Of the internal organs, the liver is by far the richest in manganese (0.273 mgm. per 100 gms. wet tissue) with kidney and pancreas next, indicating that, like other metals, manganese is mainly stored in the liver [35, 56, etc.].

The Normal Metabolism of Manganese

The absorption of manganese when taken by the mouth is normally slow, and depends upon the acidity of the gastric juice and the duration of its contact [50]. The manganese level of the blood increases during the first few hours after it is taken by mouth, but its rate of elimination is too rapid to allow accumulation in the blood, and the level soon falls to normal again.

Excretion takes place mainly (to the extent of 80 per cent.) by the faeces [31]; the bile is also at least one important path of elimination [68]; very little is excreted in the urine [18, 54]. The fact that the colon has normally a higher manganese content than any other part of the intestinal canal would seem to indicate that manganese is largely excreted through the colon [35]. Storage, as already indicated, takes place chiefly in the liver and to some extent in the kidneys [50, 56].

That manganese is able to pass through the placenta to the embryo has been demonstrated by the fact that the newly born young of parents fed on a high manganese diet contain more manganese than of those on a basal diet, while none is present in the tissues of the offspring of animals deprived entirely of manganese. This is in contrast to copper, which is apparently not transmitted through the placenta [42].

Studies on the retention of manganese by children on diets containing varying quantities of this element have shown that the amount retained is proportional to the amount ingested, indicating that manganese is essential to the physiological development of children. It is suggested that the diet for children should contain between 0.20 and 0.30 mgm. of manganese per kilogram of body weight [22].

A diet fairly high in manganese would contain meat, eggs, milk, bananas, potatoes, tomatoes, orange juice, cod-liver oil, whole grain

cereals, fruits, and vegetables such as carrots, apples, and prunes. If larger quantities were required, blueberries, pineapple, and beets would be substituted for carrots, apples, and prunes. The diet of a child subsisting chiefly on milk and refined cereals would be lower in manganese than was consistent with full growth and development.

Possible Functions of Manganese

(1) *Growth and Reproduction*.—There has been some confusion in the results obtained by feeding experimental animals with manganese. If manganese is to be proved an essential element for normal metabolism, animals must be fed on a diet deficient only in manganese and complete in all other factors. The highly purified diets used by some workers must almost certainly have been deficient in vitamins, especially vitamin B, and therefore death could not with certainty be said to be due to lack of manganese.

Other workers who observed little effect on the growth of the animals when manganese was added to the basal diet may on the other hand have used diets which contained enough manganese to satisfy their requirements [60]. Experiments with very highly purified diets, containing all other essentials including vitamins, seem to show that while young animals can grow to maturity without manganese, either the reproductive activities of the parent animals are disturbed so that they are unable to suckle the young properly [42], or the young are born with a congenital debility which makes them unable to take enough nourishment to prevent a high mortality [20]. Whether this unfavourable effect of parental manganese deficiency on the young is due, as tentatively suggested by one group of workers, to the connection between manganese and the production of a pituitary hormone essential for the functioning of the generative organs in the male and the mammary tissue in the female [42], or whether the manganese deprivation of the tissues of the embryo prevents it from growing normally to full development is still uncertain [20, 60]. In either case the effect could be explained by assuming that in the absence of the catalytic action of manganese the vital oxidation-reduction activities of both the adult and the embryo organism were inhibited, with consequent lack of full development of the growing tissues.

(2) *In Hæmoglobin Formation*.—It is well known that both young animals and infants fed on milk only are liable to develop a form of anæmia characterised by low hæmoglobin values and a diminished number of red corpuscles—a secondary (nutritional) anæmia [2, 39, etc.]. This anæmia can be improved by the addition of iron alone, but the improvement is not progressive or permanent

until the iron is supplemented by copper [61]. This discovery suggested that other metals, including manganese, cobalt, nickel, germanium and vanadium might have the same capacity, and for a time it was believed that manganese, like copper, had a specific effect in supplementing iron in the regeneration of hæmoglobin [59]. Later observations [2, 39, 61], however, using diets in which contamination with copper was strictly excluded, answered the much discussed question of the specificity of manganese in the negative. It was found that neither the formation of red cells nor of hæmoglobin was affected by manganese, though possibly it may speed up the maturation of the red cells [1]. Again, as in the case of its effect on growth, it would seem probable that whatever action manganese may have on the blood-forming organs is due more to its general catalytic activity than to any specific stimulation.

(3) *As a Catalyst*.—There is much evidence indicating that manganese must be classed among those substances, like iron, and probably copper, which are known as “enzyme catalysts of oxidation” and are together responsible for the whole process of tissue respiration and metabolism. The liberation of the energy which is essential to life is dependent upon adequate oxidation of the organic fuel materials which are derived from foodstuffs. These organic “metabolites,” which undergo oxidation with extreme difficulty in air, are readily oxidised in the tissues, on account of the presence of these enzyme catalysts. The enzymes themselves cannot perform their oxidising function unless an appropriate catalyst is present. Thus, the utilisation of molecular oxygen which is essential for the life of every cell is in itself a process due to catalysis. Even when the energy conditions are right, i.e. when the “oxidation-reduction potential” of the system is in equilibrium, so that the affinity of one reacting substance is strong enough to reduce or oxidise the other, both reagents must be “active.” Most biological substances are not active, and cannot react even with active oxidisers without the presence of a suitable catalyst.

Iron is the principal catalyst of tissue respiration, and according to the well-known theory of Warburg [65], the utilisation of molecular oxygen by the living cell is a process due to catalysis by iron, which is present as a definite complex compound, related to the hæmatin series of pigments, and called the “respiratory enzyme.”

It is interesting to note that in invertebrates the copper-containing pigment, hæmocyanin, has properties analogous to those of the iron-porphyrin compounds of the hæmoglobin series in vertebrates, while the blood of the lamellibranch, *Pinna Squamosa*, contains a pigment, pinna-globulin, very similar to hæmocyanin,

but containing manganese in place of copper [49]. The presence of manganese as a respiratory pigment has not been reported in any other animal species.

Manganese has nevertheless been found to be a powerful catalyst in the oxidation of many biological substances. Thus its presence increases the oxygenation of mono-saccharides [32]; accelerates the oxidation of cystine to cysteine [66]; stimulates the action of salivary distase, of pepsin, and of trypsin [25]; increases the autolysis of liver [48]. The oxidising activity of laccase is proportional to its manganese content [3]; and the administration of manganese stimulates antitoxin formation in animals immunised against diphtheria, indicating a direct stimulation of the antitoxin-producing cell mechanism [62].

With regard to its connection with vitamin B₁, it is to be noted that in vitamin B₁ deficiency carbohydrate metabolism is inhibited so that lactic acid accumulates in tissues, especially the brain [16, 29, 46]. It has been suggested that manganese stimulates by its catalytic activity the enzymes controlling carbohydrate metabolism which are diminished in vitamin B₁ deficiency, and the possibility arises that the symptoms of vitamin B₁ deficiency may be brought to open manifestation by a disturbance in carbohydrate metabolism partly due to a concomitant manganese deficiency in the diet [23]. It has already been noted that a diet which is deficient in vitamin B₁ will also be deficient in manganese, since the distribution of the two elements shows a close correspondence.

This question cannot be resolved with any certainty at the present moment but the whole conception of manganese as a co-enzyme or catalyst seems worthy of further investigation.

COBALT

Like manganese, cobalt is very widespread in both the plant and the animal world, though in very minute quantities.

Whether this fact indicates that it is a physiological necessity of normal tissue appears as yet to be uncertain, nor, if so, are its specific functions entirely agreed upon.

Bertrand and his co-workers, who have carried out most of the investigations on the distribution of cobalt [4-8, 10, 11], and who have examined its influence on the action of insulin in animals [6, 7], have suggested that it augments the hypoglycæmic action of insulin, but it is difficult to reach any conclusion from their work because, as in some of the earlier researches on manganese, the diets used were deficient in other essential factors and proved fatal to the animals within a few weeks.

It is certain that cobalt has an effect on the hæmopoietic system, producing a polycythæmia in small doses [30, 44, 63, 64], but whether this can be looked upon as its normal function or as a toxic effect from amounts which would not normally be derived from the ingestion of an ordinary mixed diet again appears uncertain.

It is interesting to note that the polycythæmic action of cobalt is closely interrelated with the presence of copper and manganese. Copper must be present in the diet to allow cobalt polycythæmia to develop, and manganese appears to exert a stabilising influence upon its development when it has occurred [43, 44, 45].

COBALT IN PLANT TISSUES

The distribution and prevalence of cobalt have raised the question whether, like manganese, it can be regarded as a catalyst of the nutritive exchanges of plant tissues [13].

It is present in all arable land, to the extent of a few milligrams per kilogram of soil, and a certain proportion of it is absorbed by the plants and distributed in their tissues [10].

In practically all grains and vegetables it is present in minute proportions, ranging from less than 0.02 mgm. to 0.3 mgm. per kgm. (in oats and carrots the amounts present are so small as to be undetectable by the ordinary methods of estimation) [11, 12].

In plants the leaves are generally richest in cobalt, next come grains and seeds. In trees cobalt is more abundant in the bark than the wood. Polished rice is very low in cobalt, as in the case of other minerals [11].

COBALT IN ANIMAL TISSUES

In the animal organism the presence of cobalt has been demonstrated in practically all tissues except fatty tissue and white of egg. It is present in fairly high concentration in molluscs, but very little is found in other fish [4, 5].

When animals are fed on a diet of milk, iron, and manganese only, the amounts of cobalt in the tissues are so small as to be almost undetectable—the amount in the entire body of a rat weighing 250 gm. is less than 0.01 mgm.—but when cobalt is added to the diet in amounts of 0.1 to 2 mgm. daily the total amount found increases up to 0.1 to 0.3 mgm.

Of the internal organs of these animals the liver, pancreas, and spleen contain the greatest amount [5, 8], but the vertebræ and ribs also show fairly large deposits, considerably more than the long bones [5]. This last fact may indicate that the vertebræ and ribs

are more active than the long bones in erythrocyte formation and that this is where cobalt exerts its hæmopoietic action [41, 44].

In human organs the greatest amounts have been found in the spleen (0.47 mgm. per kgm. of fresh tissue), then the liver, pancreas, and kidney. The blood contains about 0.001 mgm. per kgm.; muscle has a very low content [58].

The minuteness of the amounts normally present in the tissues seems to cast some doubt on the question of their physiological necessity, but it must be mentioned that very small amounts are also necessary to produce a definite polycythæmia. The presence of 0.04 to 0.05 mgm. in the entire body of a rat is sufficient.

Metabolism of Cobalt

Very little work has been done on the absorption and excretion of cobalt since in 1887 it was stated by Chittenden and Norris [19] of Yale University that in animals the spleen, spinal cord, and brain showed a selective absorption for the element.

A certain amount of cobalt given by the mouth is excreted in the urine; 16 mgm. have been recovered during 24 hours after the administration of food containing 180 mgm. of cobalt chloride [58].

Storage does not seem to take place in any particular organ.

Possible Functions of Cobalt

(1) *As a "Co-ferment" of Insulin.*—The fact that the pancreas of animals was found to be specially rich in cobalt led Bertrand [6, 7, 8] to speculate whether there could be some connection between cobalt and the internal secretion of the pancreas. Some experiments with dogs and rabbits, where insulin was given with and without the addition of cobalt, led him to conclude that cobalt intensified and prolonged the hypoglycæmic action of insulin, and he formulated the hypothesis that cobalt might be the "co-ferment" of insulin, just as he had supposed that manganese was the co-ferment of laccase.

Examination of the effect of cobalt administration to diabetics, however, did not give results conforming with those of the animal experiments. Some of the patients who were given cobalt with insulin improved, others did not, and those who received cobalt alone were unaffected. No further work in confirmation of Bertrand's has been done and his hypothesis remains apparently purely a hypothesis.

In this connection it may be noted that cobalt, unlike iron and manganese, does not play the part of a true catalyst, at any rate in such a reaction as the oxidation of cystine to cysteine. It does form

with cystine a cobaltous complex which is readily oxidised by air, organic dyestuffs, or ferri-cyanide, but the end-product of its oxidation is a compound analogous to an intermediary compound in the case of the iron catalyst. In other words, the iron complex and the cobalt complex behave alike in so far as both can be easily oxidised by molecular oxygen, but are different in so far as that the oxidation in the case of cobalt is very stable and forms the end-product of the reaction, whereas in the case of iron the oxidation product is very labile and involves the catalytic effect of iron [65].

(2) *As a Hæmopoietic Stimulant.*—It was found during studies of the nutritional anæmia produced in animals by a milk diet that the addition of cobalt, either alone or in combination with other metals, produced a marked polycythæmia and hæmoglobinæmia [30, 40, 45, 63, 64]. The addition of 1 per cent. of cobalt, for example, produced a red cell increase of about 53·4 per cent. and a hæmoglobin increase of about 56·2 per cent. [40]. The red cell volume was always increased but the plasma volume, the leucocyte count, and the differential leucocyte count remained unaltered [64]. These facts indicated that the effect produced by cobalt was that of a true polycythæmia (*i.e.* an actual addition of red cells to the circulation) and that it was exerted upon the erythropoietic tissue, the spleen playing no essential rôle [43].

In examining the mechanism of this erythropoietic action it becomes evident that it may be either active, *i.e.* by stimulation of the bone-marrow, increasing the production of red cells, or passive, *i.e.* by decreasing the rate of destruction of red cells and so causing a passive accumulation. The question was approached by a study of first, the effect of cobalt on the production of reticulated blood cells, an increase of which is regarded as an index of stimulation of the bone-marrow, and second, its effect on the serum bilirubin, whose decrease would be an index of diminished destruction [44].

It was found that the administration of cobalt produced a variable slight increase in reticulocytes followed by a consistent secondary rise at about the twenty-third day. The serum bilirubin was distinctly higher than normal [44]. Thus it is apparent that the polycythæmic action of cobalt is active stimulation rather than a passive accumulation.

At the same time it is possible that this stimulation may be indirect, rather than exerted directly upon the hæmopoietic tissue. It was noted in these experiments that the blood serum, besides being high in bilirubin, was bright red, indicating that hæmolysis had taken place. It is possible therefore that the accumulation of a sufficient quantity of cobalt in the organism may produce hæmoly-

sis, thus eventually increasing the serum bilirubin, which itself might then act as the ultimate stimulant of the bone marrow.

Another way in which indirect stimulation might be caused is by virtue of the vasodilatation which cobalt undoubtedly produces. It will be seen later that cobalt does produce vascular changes in the peripheral capillaries. These vascular changes may also affect the capillaries of the bone marrow, causing a local anoxæmia,* (reduced supply of oxygen) which would in itself favour increased blood formation [52].

The relation between cobalt, copper, and manganese in this polycythæmic effect of cobalt is particularly interesting. It appears that the presence of copper in the diet is necessary before cobalt can exert its stimulative effect [45]. When rats are fed on a strictly purified milk-iron diet, completely free from copper and supplemented by cobalt, anæmia develops. If copper is given together with the cobalt the characteristic polycythæmia is observed. The fact that some workers appear to have produced polycythæmia by the addition of cobalt alone may be explained by the presence in stock diets, unless carefully purified, of minute quantities of copper, sufficient to allow the cobalt action to be exerted. The action of manganese is also an auxiliary effect, but of a different nature. It appears to stabilise the effect of cobalt and to decrease its toxicity. When cobalt feeding is continued for a long time the raised erythrocytes, hæmoglobin, and blood volume tend to decrease gradually. If manganese is given also the polycythæmia produced is more intense than with cobalt alone, and even when the feeding is continued for a long period the values remain high, but the mortality of the animals is much lower. What the true interpretation of this synergistic inter-relationship between copper, manganese, and cobalt may be, is difficult to state, nor is it clear at what point the stimulant action of cobalt is exerted.

(3) *As a Stimulant of the Sympathetic System.*—It has recently been suggested that cobalt may have a specific stimulant action on the sympathetic nervous system [33].

The administration of cobalt by mouth to animals (a dosage of 5 centigrammes to a rabbit weighing 3 kgm.), and by injection to human beings (2.5 centigrammes) produces a marked vasodilatation of the peripheral blood vessels of the face and ears, lasting for 5 to 15 minutes and accompanied by a sensation of heat and a fall of blood pressure. Larger doses (4 to 5 centigrammes) in man result in more intense reddening and heat, extending to the ears and neck, with more unpleasant sensations of burning and pressure, and sometimes with abdominal pain and vomiting. These effects are pro-

duced, though not so markedly, not only by the simple salts of cobalt but also by organic salts such as the citrate and salicylate. With certain trivalent compounds, the cobaltamines, the reaction produced includes the characteristic reddening and heat, and also other symptoms such as clonic tremor of the lips, nose, cheek, and eyelids, sometimes spreading to the limbs; salivation and choking sensations. These additional symptoms are attributed to the nitrogen in the cobaltamines.

Since the erythrodermia of the face characteristic of cobalt action is not produced by nickel, which has very similar distribution and properties, it is suggested that this effect is a specific action of cobalt, exerted upon the sympathetic nervous system. It is to be noted however that some simple salts of manganese have a similar effect in dilating the peripheral blood vessels.

REFERENCES

1. BEARD, H. H., BAKER, R. W., and MYERS, V. C., Action of Fe and Fe supplemented with other elements on daily reticulocyte response, *J. Biol. Chem.*, 1931, **94**, 123.
2. BEARD, H. H., RAFFERTY, C., and MYERS, V. C., Prevention of Anaemia by means of inorganic elements, *J. Biol. Chem.*, 1931, **94**, 111.
3. BERTRAND, G., Sur l'intervention du Mn dans les oxidations provoquées par la laccase, *C.R. Acad. Sci.*, 1897, **124**, 1032.
4. — and MACHEBOEUF, M., Sur la présence du Co et du Ni chez les animaux, *C.R. Acad. Sci.*, 1925, **180**, 1380.
5. — — Sur les proportions du Co contenues dans les organes des animaux, *C.R. Acad. Sci.*, 1925, **180**, 1993.
6. — — Influence du Ni et du Co sur l'action exercée par l'insuline chez le lapin, *C.R. Acad. Sci.*, 1926, **182**, 1504.
7. — — Influence du Ni et du Co sur l'action exercée par l'insuline chez le chien, *C.R. Acad. Sci.*, 1926, **183**, 5.
8. — — Sur la teneur relativement élevée du pancréas en Ni et Co, *C.R. Acad. Sci.*, 1926, **182**, 1305.
9. — and MÉDIGRÉCIANU, M. F., Recherches sur la présence du Mn dans la série animale, *Ann. Inst. Past.*, 1913, **27**, 282.
10. — and MOKHAGNATZ, M., Sur la présence du Co et du Ni dans la terre arable, *C.R. Acad. Sci.*, 1922, **175**, 112.
11. — — Sur la présence du Co et du Ni chez les végétaux, *C.R. Acad. Sci.*, 1922, **175**, 458.
12. — — Répartition du Ni et du Co dans les plantes, *C.R. Acad. Sci.*, 1930, **190**, 21.
13. — and NAKAMURA, H., Recherches sur l'importance physiologique du Ni et du Co, *Ann. Inst. Past.*, 1934, **53**, 371.
14. — and ROSENBLATT, M., Sur la répartition du Mn dans l'organisme des plantes supérieures, *Ann. Inst. Past.*, 1922, **36**, 230.
15. — — Recherches sur la variations de la teneur en Mn des feuilles avec l'âge, *Ann. Inst. Past.*, 1922, **36**, 494.

16. BOYLAND, E., Vitamin B₁ and the co-enzyme of lactic hydrogenase, *Biochem. J.*, 1933, **27**, 786.
17. BRADLEY, H. C., Mn, a normal element in tissues of fresh-water clams, *J. Biol. Chem.*, 1907, **3**, 151.
18. CAHN, J., Über die Resorptions- und Ausscheidungsverhältnisse des Mangans im Organismus, *Arch. Exp. Path. Pharmac.*, 1884, **18**, 129.
19. CHITTENDEN, R. H., and NORRIS, The relative absorption of Ni and Co, *Studies from Lab. of Yale Univ. for 1887-1888*, **3**, 1.
20. DANIELS, A. L., and EVERSON, G. J., Relation of Mn to congenital debility, *J. Nutrition*, 1935, **9**, 191.
21. DRINKER, C. K., and SHAW, L. A., Quantitative distribution of particulate material (Mn dioxide) intravenously to cat, *J. Exp. Med.*, 1921, **33**, 77.
22. EVERSON, G. J., and DANIELS, A. L., Mn Retentions in Children, *J. Nutrition*, 1934, **8**, 495.
23. HAMAMOTO, E., Relation between B- Avitaminosis and Mn, *Orient. J. Dis. Inf.*, 1935, **18**, 21 and 57.
24. HARNACK, E., Ueber die Wirkung der Emetika auf die quergestreiften Muskeln, *Arch. Exp. Path. Pharmac.*, 1875, **3**, 58.
25. HARPUDE, K., Über den Einfluss von Ferro- und Manganionen auf Fermente, *Biochem. Z.*, 1928, **193**, 380.
26. HODGES, M. A., and PETERSON, W. H., Manganose, copper, and iron content of serving portions of common foods, *J. Amer. Dietetics Assoc.*, 1931, **7**, 6.
27. KEMMERER, A. R., and ELVEHJEM, C. H., and HART, E. B., Studies on the relation of Mn to the nutrition of the mouse, *J. Biol. Chem.*, 1931, **92**, 623.
28. — and TODD, W. R., Effect of diet on Mn content of milk, *J. Biol. Chem.*, 1931-2, **94**, 317.
29. KINNERSLEY, H. W., and PETERS, R. A., Brain localisation of lactic acidosis in avitaminosis B, *Biochem. J.*, 1930, **24**, 711.
30. KLEINBERG, W., Hæmopoietic effect of Co and Co-Mn compounds in rabbits, *Amer. J. Physiol.*, 1934, **108**, 545.
31. KOBERT, R., Zur Pharmakologie des Mangans und Eisens, *Arch. Exp. Path. Pharmac.*, 1883, **16**, 361.
32. KREBS, H. A., Über die Rolle der Schwermetalle bei der Autoxydation von Zuckerlösungen, *Biochem. Z.*, 1926, **180**, 377.
33. LE GOFF, J. M., Un nouveau vaso-dilatateur : le cobalt, *Presse Med.*, 1934, **42**, 231.
34. LEVINE, V. E., and SOHM, H. A., Effect of Mn on Growth, *J. Biol. Chem.*, 1924, **59**, p. xlviii.
35. LUND, C. C., SHAW, L. A., and DRINKER, C. K., Quantitative distribution of particulate material (Mn dioxide) to dog, *J. Exp. Med.*, 1921, **33**, 231.
36. MCCARRISON, R., Effect of Mn on growth, *Indian J. Med. Res.*, 1927, **14**, 641.
37. MCHARGUE, J. S., Cu, Mn, and Zn in metabolism of animals, *Amer. J. Physiol.*, 1926, **77**, 245.
38. — The Association of Manganese with Vitamins, *J. Agric. Res.*, 1924, **27**, 417.
39. MITCHELL, H. S., and MILLER, L., Quantitative variations in Fe, Cu, and Mn supplements, *J. Biol. Chem.*, 1931, **92**, 421.

40. MYERS, V. C., and BEARD, H. H., Influence of Fe supplements of other inorganic elements in blood regeneration, *J. Biol. Chem.*, 1931, **94**, 89.
41. — — and BARNES, B. O., Production of hæmoglobinæmia and polycythæmia in normal animals by means of inorganic elements, *J. Biol. Chem.*, 1931, **94**, 117.
42. ORENT, E. R., and MCCOLLUM, E. V., Effects of deprivation of Mn in rat, *J. Biol. Chem.*, 1931, **92**, 651.
43. ORTEN, J. M., Effect of splenectomy on Cobalt polycythæmia, *Proc. Soc. Exp. Biol. Med.*, 1934-5, **32**, 1091.
44. — On the mechanism of the hæmopoietic action of Cobalt, *Amer. J. Physiol.*, 1935-6, **114**, 414.
45. — UNDERHILL, F. A., MUGRAGE, E. R., and LEWIS, R. C., Polycythæmia in the rat on milk-copper-iron diet supplemented by Co, *J. Biol. Chem.*, 1932, **96**, 11.
46. PETERS, R. A., Harben Lectures, *J. State Med.*, 1930, **38**, 62.
47. PETERSON, W. H., and SKINNER, J. T., Distribution of Mn in foods, *J. Nutrition*, 1931, **4**, 419.
48. PRETI, L., Wirkung von Salze auf die Autolyse, *Z. Physiol. Chem.*, 1909, **60**, 317.
49. PRYDE, J., *Recent Advances in Biochemistry*, 1931, p. 346.
50. REIMAN, C. K., and MINOT, A. S., Absorption and elimination of Mn ingested as oxides and silicates, *J. Biol. Chem.* 1920-21, **45**, 133.
51. REMINGTON, R. E., and SHIVER, H. E., Fe, Cu, and Mn content of some common vegetable foods, *Assoc. Offic. Agric. Chem.*, 1930, **13**, 129.
52. REZNIKOFF, R., FOOT, N. C., and BETHEA, J. M., Etiologic and pathologic factors in polycythæmia vera, *Amer. J. Med. Sci.*, 1935, **19**, 753.
53. RICHARDS, M. B., Mn in relation to nutrition, *Biochem. J.*, 1930, **24**, 1572.
54. SCHIAPARELLI, C., and PERONI, E., Über einige neue Bestandteile normalen menschlichen Urins, *Berl. Chem. Ber.*, 1881, **14**, 117.
55. SKINNER, J. T., and PETERSON, W. H., Determination of Mn in animal material, *J. Biol. Chem.*, 1930, **88**, 347.
56. — — and STEENBOCK, H., Manganese Metabolism of the Rat, *J. Biol. Chem.*, 1931, **90**, 65.
57. — VAN DONK, E., and STEENBOCK, H., Manganese as a factor in reproduction, *Amer. J. Physiol.*, 1932, **101**, 591.
58. STARE, F. J., and ELVEHJEM, C. A., Cobalt in animal nutrition, *J. Biol. Chem.*, 1932, **99**, 473.
59. TITUS, R. W., CAVE, H. W., and HUGHES, J. S., Manganese-copper-iron-complex as a factor in hæmoglobin building, *J. Biol. Chem.*, 1928, **80**, 565.
60. VON OETTINGEN, W. F., Manganese; its distribution, pharmacology, and health hazards, *Physiol. Rev.*, 1935, **15**, 175.
61. WADDELL, J., STEENBOCK, H., and HART, E. B., Specificity of Cu as supplement to Fe in cure of nutritional anæmia, *J. Biol. Chem.*, 1929, **84**, 115.
62. WALBUM, L. E., and MÖRCH, J. R., L'importance des sels métalliques dans l'immunisation, *Ann. Inst. Past.*, 1923, **37**, 396.
63. WALTNER, K., Über die Wirkung einiger Metalle, *Arch. exp. Path. Pharmacol.*, 1929, **141**, 123.
64. — — and WALTNER, K., Kobalt und Blut, *Klin. Wschr.*, 1929, **8**, 313.
65. WARBURG, O., Iron, the oxygen carrier of the respiration enzyme, *Science*, 1925, **61**, 575.

66. — Wirkung der Blausäure auf die katalytische Wirkung des Mangans, *Biochem. Z.*, 1931, **233**, 245.
67. WICHERT, Inaugural Dissertation, Dorpat, 1860. Quoted by HARNACK, E., and SCHREIBER, F., Ueber die Resorption des Mangans in der Galle, *Arch. exp. Path. Pharmak.*, 1901, **46**, 372.
68. WURZER, K., 1833. Quoted by KOBERT, R., *see* Ref. 31.

SYNERGISM AND ANTAGONISM OF VITAMINS

BY R. TISLOWITZ, M.D.

Department of General and Experimental Pathology, Pilsudski University, Warsaw

It is well known that, as early as 1923, Hopkins [1] drew attention to the antagonistic and synergetic action of vitamins; he had observed that vitamin B prevents the harmful action of an excessive dose of cod-liver oil. In connection with the above, Harris and Moore [2] published some papers on the vitamin balance.

The isolation of certain vitamins has enabled us to study the physiological properties of vitamins, independently of avitaminosis and this led to the conclusion that the action of vitamins is often different in healthy and in avitaminotic animals.

Certain observations on administration of vitamins A, B₁, C and D to dogs are reported in the present paper; those, in connection with the results reported by other authors, have been considered from the viewpoint of the synergism and antagonism of vitamins.

Experiments were conducted on the content of cholesterol and sugar in the blood, on the duration of circulation of Congo red solution, injected into the blood-vessels, the volume of the plasma in the circulating blood, the osmotic pressure of the blood plasma, diuresis and the action of the heart.

In considering the effect of various vitamins on the content of cholesterol in the blood, it was found that lipid-soluble vitamins A or D cause an increase in blood-cholesterol (Collazo [3], Jusatz [4], Lasch [5], Wendt [6] and others), whilst the water-soluble vitamins B₁ (Hermann, Wenzel [7]) and C (Tislowitz [8]) either exercise no influence or even prevent such an increase. Some relation seems to exist between lipoids in the blood and the vitamins soluble in them.

As regards the metabolism of carbohydrates, it has been shown that vitamin C lowers blood sugar (Stepp, Schröder and Altenburger [9]). Similarly the writer observed that synthetic vitamin B₁ raises the tolerance for carbohydrates [10]. As opposed to this, the lipid-soluble vitamins A or D appear to diminish tolerance for carbohydrates (Roller [11], Tislowitz [12]).

Further, considering that in diabetes an increase of cholesterol is found and that the vitamin action on cholesterol is different, it might be concluded that water-soluble vitamins B₁ and C should be administered in diabetes, and not vitamins A or D.

The effect of vitamins on the duration of circulation of Congo red solution injected into the blood-vessels has been studied by Stern and Wilhelm [13] as well as by Tislowitz and Kurowski [14]. It was found that vitamins A or D, applied in small and average doses, increase the storing capacity of the reticulo-endothelium; this can be detected by injecting a strictly defined dose of Congo red which disappears from the blood current much more rapidly after administration of vitamins A or D than in their absence. It is possible that lipid-soluble vitamins A or D stored by the reticulo-endothelium stimulate the latter. It has been shown that, contrary to the case of vitamins A and D, Congo red solution circulates longer in the blood current after administration of vitamins B₁ and C [14]. This phenomenon cannot be attributed to any deleterious influence of vitamins B₁ or C on the reticulo-endothelium, as we know that these vitamins raise the resistance of the organism. It can be supposed that the longer duration of circulation in question is caused by the property of vitamins B₁ and C of rendering the blood-vessel walls less permeable. The action of vitamins on the reticulo-endothelium seems largely to depend on the physical properties of the respective vitamins. Lipid-soluble vitamins have the same effect as negative biological substances (Keller [15]) which are stored by the reticulo-endothelium.

As regards vitamins B₁ and C, the writer observed that within few hours after their administration, diuresis increased and it is perhaps in connection with this that a decrease in the water-content of the circulating blood was noted [16, 17, 18]. As to vitamin B₁, its dehydrating action on tissues, especially on muscle-fibres, is well known (Wenckebach [19]); the diuretic action of vitamin C in children was examined by Abbasy [20]. Diminution of the plasma volume of the blood-current was observed after application of vitamin B₁ and of vitamin C [18]. These observations on vitamins B₁ and C are corroborated by the fact that a fruit or vegetable diet, such, for instance, as lemon treatment, leads to elimination of water. On the other hand, the lipid-soluble vitamins A and D diminish diuresis at the beginning of their administration [21] and increase the plasma content of the circulating blood [22].

It seems probable that in connection with the rapid elimination of vitamin C and with greater diuresis, hypervitaminosis of this vitamin does not ensue with such ease as when dealing with vita-

mins A or D. Very large doses of vitamins A or D evoke the well-known picture of hypervitaminosis accompanied by morphological changes. On the other hand, enormous doses of vitamins B₁ or C, administered by means of intravenous injections cause only functional changes which it is difficult to define as hypervitaminotic or otherwise, as appears from the observations of Hecht and Weese [23], Schade [24], Widenbauer [25], and Tislowitz [16].

It is of interest that vitamins A and D are in certain respects antagonistic to each other: vitamin D raises the plasma content of the circulating blood from the beginning of its administration, whilst vitamin A at first lowers and then raises the plasma content of the blood-current [22].

Results corresponding with these findings were yielded by later observations on the effect of vitamins on the osmotic pressure of blood plasma [26-29]. The action of vitamins on the osmotic pressure of the blood plasma appears to precede their action on the plasma content of the blood-current and on diuresis. The action of the various vitamins on the osmotic pressure was found to be different in the case of lipoid- and water-soluble vitamins. As regards the effect of the water-soluble vitamins the polyphasic action of vitamins B₁ [29] or C [26] became perceptible within 24 hours from the first injection of these vitamins. Further administration of these vitamins did not intensify their action. The diuretic effect of vitamin B₁ and vitamin C can be explained by the findings of Fliederbaum and Tislowitz who ascertained that these vitamins exercise a rapid, polyphasic effect on the affinity of the blood for water (osmotic pressure of the blood plasma).

On the other hand, repeated doses of vitamins A or D are required in order to alter the osmotic pressure of the blood plasma [27, 28]. Here again vitamins A and D are found to be antagonistic, as also their respective influence on the plasma volume of the blood-current: as, after application of vitamin D [27], a decrease in the osmotic pressure always ensues, while vitamin A first evokes a decrease and after prolonged administration of larger doses, an increase of the osmotic pressure [28].

Administration of vitamin C and especially of vitamin B₁ to dogs caused a specific state of fatigue concurrent with a lower blood-sugar content and diminution of the volume of the blood current. At the same time distinct bradycardia and respiratory arrhythmia were noted [16, 18]. The alkaline reserve rises after treatment with vitamin C and the blood picture is displaced towards the left. All these phenomena point to vagotony resulting from administration of vitamin B₁ or C (Schade [24], Tislowitz [16, 18]).

It has not yet been possible to study the reaction of the autonomous nervous system to administration of lipid-soluble vitamins.

The results obtained to date are reviewed in the following schematic table :

Vitamins.		
	A, D.	B ₁ , C.
Content of blood sugar	tendency to rise	diminution
Tolerance for carbohydrates	reduced	increased
Content of blood cholesterol	rises	no change or diminution
Duration of circulation of Congo red in the blood current	reduced	extended
Activity of the reticulo-endothelium	increased	
Permeability of the blood vessels		reduced
Volume of blood plasma in circulation	increased	reduced
Osmotic pressure of the blood plasma. (The affinity of the blood for water)	monophasic changes; changes appear slowly and gradually	polyphasic changes, rapid and sudden. Additional doses do not intensify the effect
Diuresis during first days of administration of vitamins	inhibited	slightly increased
Elimination from the body	difficult	easy
Hypervitaminosis appears after	relatively large doses causing morphological changes	very large doses causing functional changes (vagotony, collapse)

It follows from the above table that numerous antagonisms and synergias exist between the vitamins studied. The physical factor seems to be largely instrumental in causing the difference between water-soluble and lipid-soluble vitamins. The conditions of solubility of vitamins are probably important for their resorption and elimination. Thus, usually hypervitaminosis is not observed after administration of water-soluble vitamins, but it appears after administration of vitamin A or D, which cannot pass through the kidneys with such ease as the water-soluble vitamins. The physical factor also determines the transportation of the vitamins by the blood-current, their linking to other substances, their adsorption and their storing, as, for instance, the above-mentioned specific affinity of the reticulo-endothelium to lipid-soluble vitamins.

Summing up these phenomena, a great resemblance is found between the action of vitamins B₁ and C and their antagonism to

the action of vitamins A and D, whilst the latter are antagonistic to each other.

REFERENCES

1. HOPKINS, F. G., *Brit. med. J.*, 693, 1923.
2. HARRIS and MOORE, *Biochem. J.*, 22, 1461, 1928.
3. COLLAZO, TORRES and RODRIGEZ, *Klin. Wschr.*, 13, 1678, 1934.
4. JUSATZ, *ibid.*, 13, 95, 1934.
5. LASCH, *ibid.*, 13, 1535, 1934; 14, 1070, 1935.
6. WENDT, *ibid.*, 14, 9, 1935.
7. HERMANN, *ibid.*, 8, 1752, 1929; WENZEL, *Dissert. Marburg*, 1933.
8. TISLOWITZ, *Bull. Acad. Pol. Sc.*, 311, 1935; *Z. ges. exp. Med.*, 97, 127, 1935.
9. STEFF, SCHRÖDER and ALTENBURGER, *Klin. Wschr.*, 14, 933, 1935.
10. TISLOWITZ, *ibid.*, 16, 226, 1937.
11. ROLLER, *Med. Klin.*, 898, 1936.
12. TISLOWITZ, unpublished work.
13. STERN and WILLHEIM, *Z. ges. exp. Med.*, 97, 354, 1935.
14. TISLOWITZ, *Biochem. Ztschr.*, 291, 70, 1937.
15. KELLER, *Der elektrische Faktor der Ernährung* (Berlin: Karger, 1936).
16. TISLOWITZ, *Klin. Wschr.*, 14, 1641, 1935; *C.R. Soc. Biol., Paris*, 121, 914, 1936; *C.R. III Congr. Int. Path. Comp. Athens*, II, 371, 1936.
17. — *Klin. Wschr.*, 15, 830, 1936.
18. — *ibid.*, 16, 279, 1937.
19. WENCKEBACH, K. F., *Das Beri-Beri Herz* (Berlin: J. Springer, 1934).
20. ABBASY, *Biochem. J.*, 31, 339, 1937.
21. TISLOWITZ, unpublished observations, ref. in the *Turkish Med. Ass. Istanbul*, April 1936.
22. TISLOWITZ and KUROWSKI, *Biochem. Ztschr.*, 291, 73, 1937.
23. HECHT and WEESE, *Klin. Wschr.*, 16, 414, 1937.
24. SCHADE, *ibid.*, 14, 60, 1935.
25. WIDENBAUER, *ibid.*, 15, 1158, 1936.
26. FLIEDERBAUM and TISLOWITZ, *Z. ges. exp. Med.*, 97, 121, 1935; *Bull. Acad. Pol. Sc.*, 471, 1935.
27. TISLOWITZ and FLIEDERBAUM, *Z. ges. exp. Med.*, 98, 735, 1936.
28. — — *ibid.*, 100, 775, 1937.
29. FLIEDERBAUM and TISLOWITZ, *ibid.*, 100, 780, 1937.

RECENT ADVANCES IN SCIENCE

ASTRONOMY. By R. W. WRIGLEY, M.A., F.R.S.E., Royal Observatory, Edinburgh.

THE MOUNT WILSON ANNUAL REPORT.—As usual, Dr. W. S. Adams, in the *Annual Report of the Director of the Mount Wilson Observatory*, 1936, gives a most interesting record of progress in many directions. The appearance of two bright novæ, Nova Herculis 1934 and Nova Lacertæ 1936, within a period of eighteen months afforded an unprecedented opportunity for the intensive study of this class of object, which still presents many features difficult of explanation. Nova Herculis remained relatively stable throughout the year as regards both luminosity and spectrum. Between March 1935 and February 1936 emission bands formed the most prominent feature of its spectrum, and most of these, in addition to the absorption lines, have been identified. The widths and character of the bands have shown remarkable changes, which, combined with the displacements observed in both dark and bright lines, support the now generally accepted hypothesis that the outburst of a nova is caused by an explosive impulse which drives off from the star successive envelopes of highly condensed material out of which gaseous atoms later evaporate.

Nova Lacertæ 1936 proved of exceptional interest because of the very rapid changes shown in its brightness and in its spectrum, in addition to the unusually high velocities and accelerations observed in the expanding envelope of gas. On June 24 a velocity of approach of 3400 km./sec. was measured for a strong absorption component of hydrogen. This is the highest velocity ever measured in a nova belonging to our galaxy, while accelerations up to 300 km./sec.² within 24 hours were found during the first few days after the star's discovery. The absolute magnitude of the nova was estimated by Wilson and Merrill from measures of the intensities of the interstellar absorption lines of calcium and sodium, reduced by a calibration curve based upon their results for a large number of stars. The distance of the nova is given as 800 parsecs, and its absolute magnitude at maximum as -7.2 , indicating a luminosity at least 70,000 times that of our sun. It is interesting

to note that it has been definitely identified with a star of the fifteenth magnitude.

A super-nova has been discovered by Hubble and Baade in the extra galactic spiral nebula N.G.C. 4273, one of the Virgo Cluster, and provides one of the most reliable determinations to date of the luminosity of these remarkable stars, which are the brightest objects of which we have any knowledge. At maximum its absolute magnitude was of the order of -12.4 , implying a luminosity at least 100 times that of Nova Lacertæ and 10 million times that of our sun. It was found to fade nearly three magnitudes in 100 days. Velocities of the order of 6000 km./sec. were estimated on the assumption of an expanding shell of gas. The ultra-violet spectrum showed a rapid fall of intensity towards shorter wave-lengths, disappearing completely at 23400 , and it is probable that all the light was due to emission bands. This agrees with the hypothesis, adopted from observations of galactic novæ, that the width of these bands gives an indication of the intrinsic luminosity of the star.

The light curve of this star, one of the best ever obtained for a super-nova, is given by W. Baade in *Publ. Ast. Soc. Pacific*, **48**, 226. It was observed from January 1 to May 22, and the photographic magnitude rose sharply from 17 to a maximum of 14.8 and then gradually declined to 19.2. It thus proved to be considerably fainter than two super-novæ previously discovered in other members of the Virgo cluster of nebulae. The last spectrum was secured by Baade with an exposure of over 17 hours on the nights of April 21-3. He describes it as unique, in that it consists of a single wide band of great intensity, the other bands of the earlier spectrograms having apparently all faded away. Its extreme width of 203 \AA ., corresponding to a velocity of expansion of the emitting gas shell of 6600 km./sec., is in accordance with the theoretical work of Baade and Zwicky.

At the other end of the scale are the dwarf stars with luminosities much lower than that of the sun and yet so close as to be readily observable. A search for such stars is going on at Mount Wilson, the examination being conducted among stars with large proper motions. Twelve stars have recently been found with luminosities less than one-hundredth that of the sun, and for two of these the proportion is only one ten-thousandth. Of special interest is a new white dwarf, Ross 627, whose luminosity is slightly more than one two-thousandth that of the sun. Its spectral type is about A0, and it shows the wide and shallow hydrogen lines characteristic of this class. According to the estimated parallax of $0''.089$, it is among the three faintest white dwarfs known.

Van Maanen has recently completed a study of the relative abundance of intrinsically faint stars based upon 651 stars with well-determined parallaxes. From these a formula for the mean parallax of stars of different magnitudes and proper motions has been derived. The total number of stars in the whole sky with proper motions exceeding $0''.5$ annually is about 2400, and the maximum frequency falls at visual absolute magnitude $+10.3$, representing a luminosity about one-hundredth that of the sun.

The question of the correct interpretation of the red shifts observed in the spectra of the extra-galactic nebulae has been considered by Dr. Hubble and Professor Tolman. The apparent luminosities and the luminosity gradients in nebulae must both in any case be affected by the red shifts, but the amounts will differ according to whether the red shifts really indicate receding velocities or not. A provisional analysis of the observed data has not been successful in deciding definitely which is the true interpretation, but it appears that, if the shifts are caused by velocities in an expanding universe, then the latter must have a positive spatial curvature whose radius is not greater than the observing range of the 100-inch telescope. The velocity interpretation therefore necessitates a finite universe so small that most of it can be observed without the aid of the projected 200-inch instrument. An observation by Adams and Humason bearing on this problem has been made with a grating spectrograph on the spiral N.G.C. 4151, whose stellar nucleus gives an emission spectrum. The red shift which was found agreed exactly with a previous result obtained with prismatic instruments, thus disproving the suggestion that the frequency of a vibrating light source may vary while the wave-length remains constant.¹ As the constancy of the velocity of light in its passage from the nebulae has been indicated by Strömberg's measures of the aberration of light from the distant cluster Ursa Major No. 1 (*Publ. Astron. Soc. Pacific*, 43, 266), it now appears that Planck's constant is also invariable within the same limit of error.

THE STRUCTURE, MATERIALS, AND DENSITY OF THE EARTH AND PLANETS.—The comparatively new science of seismology has thrown light on the densities and pressures of the various strata which compose the earth's crust as well as on the nature of the central core underlying them all. In *Monthly Notices R.A.S. Geophysical*

¹ In a discussion of the possible causes of the red shifts, H. J. Gramataki (*Zeitschrift für Astrophysik*, 8, 87, 1934), on the assumption that the observed loss of energy in the light quanta is due to a secular variation in the velocity of light, showed that it should appear as a Doppler effect in prismatic spectra, but should be absent altogether in grating spectra.

Supp., 3, No. 9, K. E. Bullen uses the evidence available from recent earthquake investigations to calculate the variations in density and pressure from the earth's centre to its circumference. The mean density of the core, 10.89, is found to be somewhat less than had been previously estimated. The density and pressure at the centre are found to be consistent with the existence of a central core of pure iron, with no appreciable admixture of a heavier metal such as nickel. The maximum density, encountered at a depth exceeding 6000 km., is 12.26. At the boundary of the core, at a depth of about 2900 km. the density changes abruptly from 9.93 to 5.47, this being known as the Oldham discontinuity. It was formerly considered that the density was a continuous function of the depth between 35 km. and 2900 km., but Bullen finds that, while the decrease is steady from 3.38 at 100 km. to 3.54 at 300 km., between this latter limit and 400 km. there is another discontinuity, the density jumping sharply from 3.54 to 4.08. From 400 km. to 2900 km. the variation is approximately continuous, and the mean density of the matter outside the core is 4.45. Bullen gives a table showing the densities and pressures at the various depths, and also the ellipticities of the surfaces of equal density.

In two papers in *Monthly Notices R.A.S. Geophysical Supp.*, 4, No. 1, Dr. Harold Jeffreys attempts to identify the materials composing successive layers of the earth from observations of the velocities in them of seismic waves. The continents are generally considered to be composed of a layer of granite about 12 km. in thickness based upon an intermediate layer about 24 km. thick of material probably variable, which in its turn rests upon a mass of olivine extending without much change in its composition or state to a depth of about 480 km. At this level the seismic waves show a definite change of velocity, implying a sudden change in the density of the material at a depth about 130 km. lower than was estimated by Bullen. This necessitates small alterations in Bullen's figures for the density between that level and the core, and also for the core itself, the former being increased by 0.06 and the latter reduced by 0.18. The nature of the material below the discontinuity is uncertain, and it may be either a new state of the same substance (olivine) or something entirely new. A comparison of the densities and compressibilities of various substances shows that MgO with a small admixture of FeO, or possibly a silicate more basic than olivine, would fit in with the data, but there are apparently very few materials chemically plausible which have the correct mechanical properties. J. D. Bernal has suggested cubic olivine as a possibility.

To aid in the solution of the problem Jeffreys considers the

inner group of planets, on the assumption that they are composed of the same substances as the earth. If the discontinuity observed in the structure of the latter is a change of crystal form caused by high pressure, a similar change at the same pressure should appear in all these planets, but if it represents an entirely new material there is reason to expect its appearance at a depth roughly in proportion to the radius of the body. In the case of the moon there is no sign of any discontinuity at all in structure, and even a central core seems absent. The pressure at the centre corresponds to a depth of only 150 km. in the earth, so the density of the moon is consistent with the pressure-change hypothesis, for a new material present in the earth would hardly be completely absent from her satellite. The data regarding the densities of Mercury and Venus are too uncertain for these planets to furnish a reliable test, but Mars, with a diameter nearly twice that of the moon and a mean density 1.2 times as great, should have a central pressure corresponding to that at a depth of 750 km. in the earth, and a similar discontinuity in structure should accordingly be present.

If, however, Mars is assumed to be mainly composed of olivine of which some is changed by pressure into a denser form, its calculated mass comes out too small, and it is not possible to secure agreement by any permissible change in its adopted diameter. The planet must, therefore, consist of more than one material, and agreement with the astronomically observed mass can be obtained by assuming the presence of a central core of the same type as that of the earth but much smaller. The hypothesis of a new material would also fit the data, but the amount of it required is much greater than the moon's density would suggest. The evidence from Mars is therefore indecisive, but Jeffreys considers that Bernal's hypothesis of a high-pressure change of state of olivine presents fewer difficulties than any other.

In this connection it is interesting to note that the Gold Medal for 1937 of the Royal Astronomical Society was awarded to Dr. Jeffreys for his researches into the physics of the earth and other planets, and for his contributions to the study of the origin and age of the Solar System.

PHYSICS. By W. N. BOND, M.A., D.Sc., F.Inst.P., The University, Reading.

THE MEASUREMENT OF VERY LOW TEMPERATURES.—It was suggested by Debye (*Ann. d. Physik*, **81**, 1154, 1926) and also by W. F. Giaque (*Jour. Amer. Chem. Soc.*, **49**, 1864, 1927) that it would be possible to attain very low temperatures by magnetising a strongly paramagnetic substance at some low temperature and then letting

the specimen become demagnetised adiabatically. This method was first employed by W. J. De Haas (*Nature*, **132**, 372, 1933) and has since enabled temperatures as low as a thirtieth of a degree on the Centigrade absolute scale (0.03°K.) to be attained.

At very low temperatures (as at very high temperatures) there was at first considerable difficulty in measuring the temperatures. The original method depended on Curie's law, which states that for paramagnetic substances the susceptibility per unit mass is inversely proportional to the absolute temperature. This law was known to be very nearly true at higher temperatures. By assuming its truth for lower temperatures (for some chosen substance) these low temperatures could be measured on an arbitrary scale, which over the upper part of its range agreed with the absolute scale. It was of course desirable that temperature on this arbitrary scale (the "paramagnetic temperature," T^*) should eventually be determined on the Absolute or Work scale of Kelvin. Besides the intrinsic interest in making a comparison between the arbitrary and absolute scales, a comparison was also desirable in order to elucidate the properties of the paramagnetic salts that were being used. In particular, the comparison would show to what extent the susceptibility of the substances departed from Curie's law at very low temperatures.

Nicolas Kürti, Paul Lainé and Frank Simon have now made a comparison between the "paramagnetic" and the "absolute" temperature scales, at temperatures less than one degree absolute (*Comptes Rendus*, **204**, 754, March 1937). When the total heat, Q , of a body is slightly increased, the increase in entropy, dS , is defined by the equation $dS = dQ/T$, where T is the temperature on the absolute scale; and hence $T = (\partial Q / \partial T^*)_H / (\partial S / \partial T^*)_H$. If the variations of S and Q with the "paramagnetic temperature," T^* , are found, then the absolute temperature can be deduced.

In order to find how the entropy, S , varied with T^* , they magnetised an ellipsoid of iron ammonium alum, at a known absolute temperature (about 1°K.), let it become demagnetised adiabatically, and measured the resultant "paramagnetic temperature," T^* . As the change was adiabatic, no change in entropy occurred during demagnetisation. This process was carried out for various values of the initial magnetising field. Now, the variation of S with the initial field (at 1°K.) can be calculated from the Langevin-Brillouin theoretical magnetisation curve; and in each experiment the final value of S at nearly zero field and temperature T^* was the same as the value of S when the specimen was magnetised and at about 1°K. Hence the variation of S with T^* can be deduced at once.

To find how the total heat, Q , varied with T^* , they supplied thermal energy at a constant rate (by letting γ rays be absorbed in the apparatus), and measured the paramagnetic temperature, T^* , after various intervals of time. It only remained to determine the rate of supply of thermal energy; and this was obtained from the knowledge that the value of T^* approximates to the value of T at the higher temperatures (where T is known).

At temperatures greater than 0.1°K. , the "paramagnetic temperature" T^* was almost equal to the absolute temperature T deduced from the equation $T = (\partial Q / \partial T^*)_H / (\partial S / \partial T^*)_H$. At about 0.06°K. , T^* was appreciably less than T ; but at about 0.035°K. the difference between them was very small. Finally, at 0.034°K. , T^* decreased very rapidly, till it became rather less than half as big as T .

From their results it was possible to deduce curves showing the variation of specific heat and entropy with absolute temperature, for iron ammonium alum. These curves gave evidence that the alum had a Curie point at about 0.034°K. , being ferromagnetic at lower temperatures.

In a letter to *Nature* (139, 878, May 22, 1937) J. F. Allen and E. S. Shire describe experiments they have made on the resistance of a piece of fine phosphor-bronze wire at temperatures below 1°K. They measured the "paramagnetic temperature" using iron ammonium alum either in granular form or in a roughly cylindrical form (about eight diameters in length). These specimens are of different shape to the ellipsoid (of axial ratio 8 : 1) used by Kürti, Lainé and Simon; and hence Allen and Shire were unable to use the results discussed above to reduce their values of T^* to the absolute scale. They give graphs relating $R/R_{4.2^\circ \text{K.}}$ and T^* , which show a peculiarity at about 0.034°K. This probably corresponds to the peculiarity in the (T^*, T) curve; and it is likely that if the value of $R/R_{4.2^\circ \text{K.}}$ were plotted against the absolute temperature, T , there would not be any kink at 0.034°K.

They are unable to tell whether phosphor bronze would become supraconducting at some temperature below 0.034°K. ; but they decide that, for a given specimen, a phosphor-bronze resistance thermometer can be quite conveniently used in the range of temperature below 1°K. , and possesses approximately the same accuracy as does the ballistic measurement of susceptibility for the determination of T^* .

A STANDARD SOURCE OF SOUND AND THE MEASUREMENT OF MINIMUM AUDIBILITY.—Various methods have been used for measuring sound intensities in absolute units. For instance,

measurements may be made with the Rayleigh disc ; or a standard source of sound may be devised, such as a piston moving with a simple periodic motion of known frequency and amplitude.

In 1931 Professor Andrade suggested a new type of standard source (*Discussion on Audition*, Physical Society, 1931, p. 79). One end of a cylindrical tube was to be closed by the diaphragm of a loud-speaker, the other end being open and provided with a large plane baffle. The baffle was used in order to confine the emitted waves to the half space ; and the amplitude of the waves in the air inside the tube was to be measured by observing the traces of smoke particles at an antinode. A recent paper (E. N. da C. Andrade, and R. C. Parker, *Proc. Roy. Soc., A*, **159**, 507, April 1937) describes the development of such a source of known amplitude and its application to the measurement of the minimum sound energy that is audible.

In order that it should not be necessary to measure the amplitude of the motion of the smoke particles on every occasion, the oscillator, amplifier and loud-speaker unit were designed to be very stable in their action. It was then possible to determine the input current necessary to produce a specified amplitude of motion of the smoke particles. Moreover, the amplitude was found to be directly proportional to the input current over the range of conditions employed. The oscillator frequency was always adjusted so as to be equal to the resonance frequency of the tube (about 400, 500 or 600 cycles per second).

It was necessary to surround the cylindrical tube with a thermostatically controlled tank, to prevent convection affecting the motion of the smoke particles. Various types of smoke were tried, that finally adopted being produced by burning magnesium ribbon. The smoke was fanned for some minutes before it was used, to produce particles of suitable and reproducible size. The mean radius of the particles, as determined by measuring the extent of the brownian displacement in a given time, was about 3×10^{-5} cm. It was calculated that such particles should vibrate with about 0.9999 times the amplitude of the air vibration. This prediction was confirmed experimentally, by noticing that the amplitude was the same for particles of appreciably different size.

The apparatus was then used to measure the minimum energy necessary for audibility. The standard source was mounted near the top of a building, with its baffle flush with the wall ; and the observer was on the top of a neighbouring building. The ground between was covered with sawdust, and the experiments were carried out between 1 and 4 a.m. on Sundays, when there was very

little extraneous noise. The results compare satisfactorily with those of certain other experimenters. One interesting observation may be mentioned. At 410 cycles per second, the minimum energy necessary for audibility was definitely less when the sound was being increased in intensity (till first audible), than when it was subsequently being diminished (till it was inaudible). This effect was attributed to aural fatigue. The difference between these two threshold energies was about 12 per cent.; but at a frequency of 646 per second the effect did not occur.

MAGNETIC HYSTERESIS.—The magnetisation curve has been measured for single crystals of ferromagnetic substances, but in almost all cases short straight specimens have been used. In order to interpret the results, however, it is necessary to allow for the demagnetising field due to the free poles at the ends of the specimen; and for short cylindrical specimens the demagnetising factor is not accurately known. In an attempt to overcome this difficulty, K. J. Sixtus (*Phys. Rev.*, **51**, 780, May 1, 1937) has carried out measurements using a ring cut from a single crystal of iron. When a current is passed through a toroidal solenoid of wire wound on the ring, there will be no demagnetising field in the usual sense, as the magnetising field is circumferential, and the specimen has no ends. A cubic crystal has, however, six directions of easy magnetisation; and the field changes its direction relative to these axes as we pass round the ring. Consequently, free poles may be produced on the sides of the specimen; but their demagnetising effect may be assumed to be relatively small.

Now, according to Kaya (*Zeits. f. Physik*, **84**, 705, 1933) and C. J. Gorter (*Nature*, **132**, 517, 1933), the remanence of single crystals is not zero, but is equal to $I_s/l + m + n$, where I_s is the saturation value of the intensity of magnetisation and l, m, n are the direction cosines of the field with respect to the crystal axes. K. J. Sixtus finds that his results confirm that there is a finite remanence, of the order of magnitude predicted. The value of I decreases from about 1560 at $H = 100$ to about 900 at $H = 0.02$, then decreasing to zero for a "coercive force" or reversed field of about 0.18. There is evidence that the value of the coercive force depends on the direction of magnetisation relative to the crystal axes.

It has been shown experimentally (Shoenberg, *Proc. Roy. Soc., A*, **155**, 712, 1936) that there is no hysteresis in the magnetisation curve of a superconductor provided it is pure and has an ellipsoidal shape. This result has been explained theoretically, but it has not been found possible to predict what will occur for non-ellipsoidal specimens. In a recent paper (*Proc. Camb. Phil. Soc.*, **33**, 260,

April 1937) D. Shoenberg gives an account of extensive experimental work on the magnetisation curves (at a temperature of a few degrees absolute) of short cylinders of tin, lead, and tantalum, placed longitudinally or transversely in the field.

THE VALUES OF ATOMIC CONSTANTS.—The numerical values of certain fundamental atomic constants have been discussed by R. Ladenburg, of Princeton (*Ann. der Physik*, **28**, 458, Feb. 1937) and by Sten von Friesen, of Uppsala (*Proc. Roy. Soc.*, **A**, **160**, 424, June 1937). Their conclusions are most easily presented in tabular form :

	Ladenburg.	von Friesen.
$c \times 10^{-10}$ cm./sec.	2.99774 ± 0.00011	2.99780 ± 0.00020
$(e/m_0) \times 10^{-7}$ e.m.u./gm.	1.7576 ± 0.00026	1.7585 ± 0.002
$e \times 10^{10}$ e.s.u.	4.803	4.800 ± 0.005
$h \times 10^{27}$ erg-sec.	6.627 6.609	6.610 ± 0.015
$hc/2\pi e^2$	137.06 136.69	136.9
	From Rydberg's Constant	From limit of X-ray spectrum

A. E. Shaw (*Phys. Rev.*, **51**, 887, May 15, 1937) gives a preliminary account of a new determination of e/m for electrons (by a method that involves magnetic and electrostatic focusing of a beam of electrons). The preliminary value given is

$$e/m_0 = (1.7571 \pm 0.0013) \times 10^7 \text{ e.m.u./gm.}$$

ULTIMATE PARTICLES.—For several years it has been customary to account for the continuous β -ray spectrum of radioactive bodies by postulating an elementary particle called a neutrino. This supposed particle, of small mass, no charge, very small magnetic moment, but having angular spin momentum, has not been detected and appeared to be undetectable. Dr. F. L. Arnot (*Nature*, **139**, 1065, June 19, 1937) believes that the β -ray spectrum can be accounted for without assuming the existence of undetectable neutrinos. Dr. Arnot's explanation depends on considerations of energy interchanges between an atomic nucleus and the "background." Following Eddington, we might describe the "background" as the quantum physicist's method of treating the "rest of the universe" (the part that it was hoped was unimportant!).

S. H. Neddermeyer and C. D. Anderson, in a paper entitled "Note on the Nature of Cosmic-Ray Particles" (*Phys. Rev.*, **51**, 884, May 15, 1937), conclude that certain penetrating particles can apparently only be explained by one of the following hypotheses :

(a) that an electron (+ or -) can possess some property other than its charge or mass, or (b) that there exist particles of unit charge, but with a mass larger than that of an electron and much smaller than that of a proton. In a footnote they say that Street and Stevenson (*Abstract* No. 40, Meeting of American Phys. Soc., April 29, 1937) have just reported excellent experimental evidence for particles such as postulated in (b) above.

METEOROLOGY. By E. V. NEWNHAM, B.Sc., Meteorological Office, London.

GREAT AMERICAN FLOODS.—The incidence of two such extraordinary floods as those of March–April 1936 and January 1937 in the United States has drawn more than usual attention to the meteorology of American floods. In particular C. F. Brooks and A. H. Thiessen have made a special study of this subject and have published their conclusions in a joint paper that appeared last spring.¹ Widespread and persistent falls of heavy rain in temperate latitudes are generally due to the interaction of cold wind currents of polar origin and warm moisture-laden winds of tropical origin. The meteorological history of the great American floods shows that in the United States the general rule is followed, for the authors of the paper just mentioned state that “two elements are always involved in the production of a great flood in the eastern United States: a rapid and continuing flow of moist tropical air into the country and a frequent or persistent elevation of this tropical current by a colder air mass over the same region.” They give a table with particulars of thirteen great floods between 1882 and 1937, some of which extended over two or three months. A curious point about this table is the information that it gives about the seasonal variation of great floods: none of these occurred in or extended to August, September or October, and only one in each of the months November and December. One might conclude from this that the period from mid-winter to July is the portion of the year when great floods are most likely to occur, in spite of the statement made two pages later that great floods occur only in winter and spring. The table actually shows, moreover, that there has been in the period considered one more flood in May than in any other month, July being next in company with January and April. In a section of their work dealing with the seasons of great floods the authors bring forward a number of reasons why a given

¹ “The Meteorology of Great Floods in the Eastern United States,” by Charles F. Brooks and Alfred H. Thiessen, *Geographical Review*, Vol. XXVII, No. 2, April 1937, pp. 269–90.

amount of rain in the summer should be less effective in flood production than the same amount in winter. Among these is the greater evaporation in summer and the influence of vegetation, which last is said to be "an effective interceptor of rain, a mechanical hindrance to run-off and a rapid user of ground water." Perhaps more stress on the first and last of these four influences would have led to better agreement with observed seasonal variation, for broadly speaking evaporation in excess of precipitation continues throughout the summer half of the year, as does the "thirstiness" of vegetation, and these two processes would tend to make the soil's moisture content least at the close of summer and beginning of autumn; capacity of the soil to absorb heavy rainfall is obviously an adverse factor for flood development and in only two out of the thirteen great floods the previous condition of the ground is recorded as having been dry.

Turning now more particularly to the Ohio-Mississippi flood of January-February 1937, in December 1936 the sub-permanent high-pressure area of the southern part of the North Atlantic expanded westwards from its normal position into the Bermuda region, with the result that great quantities of moist tropical air passed from the Caribbean Sea into the Gulf of Mexico and entered the American continent. By January 1937 it had come about that a band of northward-moving air about 2000 miles wide covered the region from somewhere east of Bermuda to the Mississippi and a little beyond. This met a southward-moving band of polar air, also about 2000 miles wide, that extended from the plains to the Pacific coast. The temperature contrasts that resulted were phenomenal. A map showing the average departure of the temperature from the normal for the season during the week January 19-26 gave a difference of more than fifty degrees Fahrenheit between the deviations from normal at the foci of the two areas of opposed anomaly. Throughout the month there were strongly marked fronts running roughly from south-west to north-east, and there were incessant heavy rains. During the ten days January 14-25, 13.69 inches were recorded at Memphis and 15.00 inches at Louisville, and throughout the Ohio River, except at Pittsburg, the river level reached the highest ever known. The discharge from this river was so great that for a time it reversed the flow in the Mississippi above the junction of the two rivers. There are close parallels between the meteorological events of this flood and some of the earlier ones, notably that of January-March 1913, except that all the events of that year took place a little farther north. March 1922, January 1882 and December 1926 are also closely analogous, but with some

displacement of the area of heaviest rainfall. The floods of March 1936 are of particular interest in that orographical rainfall apparently played an important part. The orographical rain seems to have intensified the frontal rain where the contours of the land provided sufficient obstruction. For example, at Pinkham Notch, at an elevation of 2000 feet on the south-east slope of Mt. Washington, N.H. (6300 feet), 6.46 inches fell on March 12 alone. This was followed by 10.32 inches on the two days March 18 and 19, the total for the fourteen days March 9-22 being 22.43 inches. The south-east winds on the mountain reached a speed of 158 miles an hour at one time during this period.

The general conclusion reached by the authors in their survey is that the incidence of great floods requires the simultaneous presence of two essentials: firstly, the continued presence of an area of high pressure over the southern part of the North Atlantic in such a position that the moist south-east winds on its south-western side pass directly into the American continent, and secondly, the existence of southward-moving masses of polar air which elevate the damp warm air when the two currents meet.

"KINEMATICAL FEATURES OF DEPRESSIONS."—A memoir with the above title has appeared recently.¹ It is a study primarily of the depression of temperate latitudes considered as a vortex—a subject that at one time occupied the attention of Aitken, Rayleigh, Shaw and others, especially in the years 1915-18, but one which has tended to be overlooked since the Norwegian methods of analysis have greatly occupied the attention of meteorologists. This memoir attempts an analysis of air movements at different distances from the centres of a few depressions that were of a suitable size and suitably placed for a study of this kind, taking into account the existing distribution of anemometers giving a continuous record of the direction and speed of the wind. It is only a small proportion of primary depressions that are suitable for such studies, because most pass to the north of the British Isles and are so large that observations would only be available over a small part of their extent. Although the first object of the analysis was to establish general average relationships between air movement and distance from the centre of the depression, differences of air mass were recognised and taken into account, notwithstanding that in the case of air masses of tropical origin the difficulty was encountered that such air can only be studied with the aid of anemometer records so long as it extends down to the ground, *i.e.*

¹ *Meteorological Office, Geophysical Memoirs*, 8, No. 72, 1937, "Kinematical Features of Depressions," by A. H. R. Goldie, D.Sc.

so long as the depression has a "warm sector." The analysis led to the conclusion that except in a central area of the depression the average air movement at the earth's surface is roughly that of a simple vortex (velocity varying inversely as the distance from the centre). This was the case both in the front and rear of the depression, and was most nearly true in the cold (polar) air masses. In regard to the central area referred to in the last sentence but one, an approximation of average speed to distance from the centre, *i.e.* what would have been rotation like a solid disc except that there was considerable incurvature, was sometimes found in the polar air, but on the other hand it was observed that in such cases as were found of tropical air approaching the centre, a fairly constant and high average speed was maintained up to the centre. Some evidence was obtained that the diameter of the central area of polar air, with velocity approximately inversely to the distance from the centre, increases as the depression advances in age. Apart from these relationships between the average air motion and distance from the centre, there was revealed a cell-like structure; there was convergence both of cold and warm air below a height of 2 km. towards a part of the main front dividing the polar from the tropical air masses and passing through the centre of the depression, and upward motion from it. Some resemblance was found here with the observed motion in small model convectional cyclones made by Aitken many years ago. In two cases that were studied in detail a line of convergence was found in the tropical air about 400 km. south of the warm front.

Turning to the problem of the cause of cyclone formation, a study of the circumstances attending the development or increase of intensity of depressions led to the conclusion that the required energy was derived mainly from the high speed of the tropical air, especially in the higher levels of the atmosphere, *i.e.* from the general planetary circulation of wind; the trigger action required to begin the process of formation or intensification was thought to be the warming and humidifying of the polar air where it borders the warm front (further analogies with Aitken's models were found here). No evidence was found of gravity waves causing cyclone formation. There was support for the idea of the main polar front as a horizontal vortex line, any point on which is a potential point of origin of a depression which would result from a suitable disturbance from below of the stability of the cold and warm air masses.

These general conclusions were shown to be consistent with statistical relationships found by W. H. Dines between pressure and temperature in the troposphere and stratosphere, and to sup-

port in a general way the Norwegian conceptions of warm and cold fronts in depressions and the association of areas of precipitation with them.

BIBLIOGRAPHY OF DEPRESSIONS

- J. AITKEN, *Trans. Roy. Soc. Ed.*, **40**, 1900-1; *Proc. Roy. Soc. Ed.*, **36**, 1915; *Proc. Roy. Soc.*, A, **94**, 1918, 250-9.
- W. H. DINES, *J. Scot. Met. Soc.*, **16**, 1914, 304-11; *Q.J. Met. Soc.*, **51**, 1925, 31-8.
- W. H. DINES and L. H. G. DINES, *Q.J. Met. Soc.*, **49**, 1923, 167-76.
- A. H. R. GOLDIE, *Q.J. Roy. Met. Soc.*, **49**, 1923, 6-20; *Geophysical Memoir, Met. Office*, No. 63, 1935; *ibid.*, No. 53, 1931; *ibid.*, No. 69, 1936; *Q.J. Met. Soc.*, **51**, 1925, 239-46; *Proc. Roy. Soc. Ed.*, **45**, 1925, 213-29.
- LORD RAYLEIGH, *Proc. Roy. Soc.*, A, **93**, 1917, 148-54; *Phil. Mag.*, **32**, 1916, 529-46.
- SIR NAPIER SHAW, *Proc. Roy. Soc.*, A, **94**, 1917, 34-52; *Geophysical Memoir, Met. Office*, No. 12, 1918; *ibid.*, No. 19, 1922.
- W. N. SHAW and R. G. K. LEMPFERT, *Life History of Surface Air Currents*, London, 1906.
- D. BRUNT, *Proc. Roy. Soc.*, A, **99**, 1921, 397-402.
- and C. K. M. DOUGLAS, *Mem. Roy. Met. Soc.*, **3**, No. 22, 1928.
- SIR GILBERT WALKER, *Q.J. Met. Soc.*, **59**, 1933, 389-96; *ibid.*, **56**, 1930, 59-66.
- I. M. CLINE, *A Century of Progress in the Study of Cyclones*, New Orleans, 1935.
- L. D. SAWYER, *Prof. Note, Met. Office*, No. 50, 1928.
- V. H. RYD, *Medd. Dansk. Met. Inst.*, No. 7, 1927.
- J. DUEWARD, *Prof. Note, Met. Office*, **4**, No. 42, 1925.
- C. K. M. DOUGLAS, *Q.J. Met. Soc.*, **48**, 1922, 342-56; *ibid.*, **50**, 1924, 339-63; *ibid.*, **55**, 1929, 123-51.
- T. BERGERON and G. SWOBODA, *Wellen und Wirbel an einer quasi-stationären Grenzfläche über Europa*, Leipzig, 1924.
- S. FUJIWARA, *Q.J. Met. Soc.*, **47**, 1921, 287-93.
- W. H. PICK, *Met. Mag.*, *Met. Office*, **66**, 1931, 125-9.
- A. WEGENER, *Met. Zeit.*, **45**, 1928, 201-14.
- W. PEPPLER, *Beitr. Phys. frei. Atmos.*, Leipzig, **11**, 1924, 79-95.
- S. N. SEN, *Geophysical Memoir, Met. Office*, No. 25, 1925.

BIOCHEMISTRY. By W. O. KERMAK, D.Sc., LL.D., F.R.S.E., Research Laboratory, Royal College of Physicians, Edinburgh.

WHITE v. WHOLEMEAL BREAD.—It is perhaps true to say that, in relation to the problem of human nutrition in general, scientific knowledge has been accumulated much more rapidly than it has been found possible to apply it in practice. There is little doubt but that a dictator of diets, established in Great Britain at the present time, with unlimited power over men and materials, could, with a few strokes of the pen, at once raise physique and well-being to a very significantly higher level than that which now exists. But there has been one curious exception. It concerns

the commonest of all our foodstuffs, ordinary bread. For the last quarter of a century a public controversy has raged over the alleged inadequacy of white bread as a suitable stable foodstuff. It was generally agreed that the modern white breads were very poor in vitamin content, whereas there was some evidence that wholemeal wheaten breads contained at least some vitamin B. It has been held by the one school of thought that large numbers of the community, whilst not showing frank signs of vitamin B₁ deficiency (beri-beri), do actually suffer chronically from a persistent under-consumption of this anti-neuritic factor. In particular they attribute much illness due to gastric and other digestive disorders to this cause. Against this it is argued that an ordinary good mixed diet, apart from bread altogether, is likely to provide an adequate supply of vitamins of the B group, and that at the very worst, only a small minority of the population—the extreme cases of inadequate or unwise diet—suffer from this particular type of chronic deficiency. According to the first point of view, the universal popularity of white bread, made from flour almost wholly deprived of vitamin B, is a foolish, and strongly anti-social fashion to be challenged and if possible altered; the second attitude would regard this campaign as a passing ramp based on inadequate knowledge of the facts and probably entirely misdirected.

In order to decide between these rival views it is clearly necessary to know three things; first, the average daily requirement of the human subject in respect of vitamin B₁; second, the amount of the vitamin contained in the diets ordinarily consumed throughout the country; and third, the vitamin B₁ contents of the various types of bread. A few years ago, it was impossible to reply to these questions with any degree of certainty, but various recent investigations have provided reliable answers, and so enabled the controversy to be decided. As we shall see, those who roundly condemn the modern white loaf appear to have had the best of the argument.

The last of the three points mentioned above—it is convenient to take this first—has been investigated by Harris and Leong (*J.S.C.I.*, 1937, 56, 195T), Harris (*Biochem. J.*, 1937, 31, 799), Leong and Harris (*Biochem. J.*, 1937, 31, 812) and Baker, Wright and Drummond (*J.S.C.I.*, 1937, 56, 191T). Before stating their results, it is of some interest to refer to the method of assay employed. Of the various components of the vitamin B complex, it is the anti-neuritic factor, aneurin, vitamin B₁, which is chiefly in question. The original method of testing a substance for the presence of this factor was to administer it to pigeons, or other suitable test animals, which had developed convulsions as the

result of prolonged deprivation of the vitamin. A more recent method is that which depends on the observation of the rate of growth of rats. In the absence of vitamin B₁ in the diet, otherwise complete, the growth is retarded, but is then remarkably accelerated after the administration of aneurin. Harris and Leong (*loc. cit.*) find that this method breaks down when it is used for the assay of vitamin B₁ in bread. The reason is a somewhat curious one. When the rather large amounts of the starchy materials which are required to supply reasonable quantities of the vitamin are given to these animals in their food, a characteristic digestive disorder known as refection ensues. Some animals pass large white faeces; simultaneously the symptoms of vitamin deficiency disappear and the experiment has to be discontinued. This peculiar condition has been described by Fredericia and others (*J. Hyg.*, 1928, **27**, 70) and Roscoe (*J. Hyg.*, 1928, **27**, 103). The aetiology of the condition is not yet completely understood; in some mysterious way it seems to affect certain laboratories more than others. Methods depending on the cure of convulsions in animals are also unsuitable for assaying substances like bread, relatively poor in the vitamin, for, in practice, it is found difficult or impossible to administer the large doses required to cure an animal already almost *in extremis*.

These difficulties are avoided by the use of the bradycardia method developed by Birch and Harris (*Biochem. J.*, 1934, **28**, 602). This depends on the fact that, when rats are kept for three or four weeks on a diet lacking in vitamin B₁, the heart rate falls from the normal value of 500–550 to about 300 beats per minute. The administration of vitamin B₁ rapidly brings about an acceleration in the heart rate. If sufficient is given the normal level is restored. With smaller doses a definite but less marked effect is observed. In practice, observations are made by means of the electrocardiograph before, and every twelve hours after, the administration of a suitable single dose of the substance to be assayed. The number of days which elapse between the giving of the dose and the return of the rate to the initial low level is thus found. Observation shows that, within limits, this period is proportional to the quantity of the vitamin administered. As in all similar biological assays, it is necessary to make observations on several animals, and take the average result in order to eliminate individual variation. When the proper precautions are taken the method is reasonably accurate, the error being of the order of perhaps 10 per cent. Further, it is specific for vitamin B₁—the earlier tentative claims of the authors in this respect have since been supported

by work with the pure crystalline vitamin. The fact that the effect is produced by a single dose, and does not involve prolonged feeding of the rat with the material to be assayed, avoids the difficulties of refection, so troublesome when the rat growth method is applied to farinaceous materials of low vitamin content. As compared with the rat or pigeon convulsion method, it has the advantage that the bradycardia makes its appearance whilst the animal is still relatively well and able to eat, and so the difficulty of administering the dose, met with in the convulsion method, does not arise. It is thus the only satisfactory method for the assay of farinaceous materials of relatively low vitamin content, such as the various types of breads and flours at present consumed by the public.

Harris finds that ordinary white bread contains less than 0.2 international units per gram of vitamin B₁. Bread made from wholemeal, that is, including the wheat germ and the pericarp or bran, as well as the starchy endosperm, usually contains over 0.8 units per g., and may be as high as 1.0 unit per g. Bran loaves occupied an intermediate position—the samples analysed contained about 0.5 unit per g. It is interesting to find that bread to which special wheat germ preparations had been added, and which might therefore have been expected to be specially rich in the vitamin, did not, in fact, show any striking superiority over the simple wholemeal loaf. The assays of bread reported by Baker, Wright and Drummond, which were also carried out by the bradycardia method, gave results in substantial agreement with those of Harris.

In the course of a general discussion of the whole question, Baker, Wright and Drummond give some very interesting historical information. It appears that in England, the preference for whiter and whiter bread began to manifest itself towards the end of the eighteenth century, a possible cause being the prevalence at that time of inferior, crude and unwholesome dark-coloured breads. The standard English flour was then stone-ground, and though sieved through wool or linen cloth, contained sufficient of the germ and bran to give it a vitamin content of about 1.5 units per g. Developments, which took place about the middle of the nineteenth century, in the technique of milling, especially the introduction of the roller mill, which removed the germ and bran very effectively and produced a fine white flour, resulted in the flour ordinarily used in this country being almost entirely deprived of its vitamin content—Harris finds that various samples purchased in the ordinary market contained from 0.2 to 0.3 unit per g.

We now go on to enquire whether this loss of vitamin is likely

to be of serious practical importance. To do this, it is first necessary to answer the other two questions raised above. Information as to the amount of vitamin B₁ required by the normal adult to prevent beri-beri has been collected by Cowgill (*The Vitamin B Requirement of Man*, 1934, Yale University Press). He suggests a formula, according to which this preventative daily dose for any animal species is proportional both to the maximum size of the adult, and to the actual energy expenditure in calories. This is presumably a level of intake below that required for perfect health, for there is evidence that animals kept for a long period of time on a diet adequate to prevent beri-beri may yet show a general impairment of health as the result of chronic vitamin B₁ insufficiency. Thus Baker, Wright and Drummond report that, of 556 mice kept for several years on a diet poor in vitamin B₁ but sufficient to protect against beri-beri, a much larger number developed gastro-intestinal troubles as well as cardiac and renal disorders than in the control group. This supports the view that similar chronic B₁ insufficiency may exist in human populations quite free from beri-beri. These authors come to the conclusion that a really adequate diet for male adults ought to contain at least 500 international units per day. For any particular individual, the precise figure will depend on his size, and may be affected by special peculiarities of metabolism; but we may take 500 units as the average lower limit. Do the diets ordinarily consumed throughout Great Britain provide this amount of the vitamin?

To calculate the vitamin content of any given diet we must know the vitamin content of the various foodstuffs. A large amount of work has been carried out on this question. Much information has been collected in Cowgill's monograph, and we may also refer to a paper by Baker and Wright (*Biochem. J.*, 1935, 29, 1802) who, using the bradycardia method, estimated the vitamin B₁ content of a large variety of food products. A considerable amount of information is now also available as to the diets ordinarily eaten by various classes of the community. By combining these data, Baker, Wright and Drummond find that the average working-class diet contains only about 300 units of vitamin B₁, evidently well below the minimum requirement. Diets of even well-to-do classes were found to contain only 450-550 units, so that even these relatively sumptuous menus were barely protective against vitamin deficiency.

What, then, would be the effect of substituting wholemeal bread for white bread? It appears that, over a wide range of income levels, the average consumption of bread remains remarkably con-

stant—about 66 ounces per week, or slightly over 250 g. per day. This quantity of white bread is not likely to contain more than about 30 units, whilst as good wholemeal bread, properly prepared, it should contain over 200 units. Thus the alteration in the type of bread eaten would at once raise the vitamin B₁ content of the diets consumed in this country from 300–500 units to 500–700 units. It would, in fact, raise the intake of this factor from a subnormal to an adequate level. This important result would seem to be one calling for immediate attention from the authorities.

Baker, Wright and Drummond refer briefly to some very interesting historical facts relating to diets in the past—they promise us a fuller account of the subject later. People used to eat more bread than they do now, perhaps 20 ounces per day instead of about 10. This no doubt meant, in general, a lower standard of living, but assuming that it was the old-fashioned variety of good quality (stone-ground), it did at least provide a liberal supply of vitamin B₁—over 400 units might come from this source alone. Various records are available of diets provided in particular circumstances in the past. The results of calculations by Baker, Wright and Drummond are shown in the following table :

Date.	Diet.	Units B ₁ per day.
1615	Suggested diet for seamen	640
1670	Soldier's ration	1000
1686	Patients in Bart.'s	360–700
1782	Parish poor	660–850
1830	Diet of John Dalton	1230
1836	Prisoners, Ipswich prison	700
1838	Poor Law Diet, City of London	1060
1838	Poor Law diet, Dudley Union	600

As the authors remark, “the best-fed members of the population to-day, whilst getting twice as much vitamin B₁ as people on a low income level, yet consume less vitamin B₁ than the parish poor of the eighteenth and early nineteenth century.” It would seem then that life in Merrie England in the good old days did have its advantages after all, at least as far as vitamin B₁ is concerned. Our present problem might perhaps be more easily solved if attractive wholemeal breads were available at prices at least as low as those of the common variety.

CATALASE, PEROXIDASE AND CYTOCHROME *c*.—Considerable advances have recently been made in our knowledge of enzymes, and, in particular, of those which contain hæmatin or a hæmatin derivative as a prosthetic group. It has been known for some

time, for example, that catalase, the enzyme which brings about the decomposition of hydrogen peroxide with the liberation of molecular oxygen, consists of a hæmatin group in association with a protein. A standard example of this type of hæmatin-protein complex is, of course, hæmoglobin, but spectroscopic evidence indicates that catalase is analogous, not to hæmoglobin itself, but to methæmoglobin. The essential difference is that in methæmoglobin, the iron is in the ferric state, the protein, globin, here being combined with the oxidised hæmatin. Hæmoglobin, on the other hand, contains reduced hæmatin, the iron being here in the ferrous state. As a result there is a characteristic difference in the spectrum of the two compounds. The catalase spectrum is analogous to that of the methæmoglobin. On general grounds it seemed probable that the prosthetic group of catalase would prove to be actually identical with that of methæmoglobin—that is to say, that it would be the hæmatin derived from protoporphyrin and not from some allied porphyrin such as hæmato- or mesoporphyrin. It is interesting, therefore, that Stern (*J. Biol. Chem.*, 1935, **112**, 661) has now isolated the prosthetic group of catalase and has produced strong evidence that this presumption is, in fact, correct. This evidence is first, its conversion into a crystalline porphyrin derivative of known constitution, and second, the demonstration that it combines with the native protein, globin, to give a compound indistinguishable from methæmoglobin and converted into hæmoglobin on reduction. As hæmatin has been synthesised by Fischer, and is therefore of definitely known constitution, the exact structure of the prosthetic group of catalase is now completely known.

Some years ago Kuhn, Hand and Florkin (*Hoppe. Seyl. Zeit.*, 1931, **201**, 255) found that the enzymatic activities of highly purified peroxidase preparations were proportional to their hæmatin contents, the latter being estimated by conversion of the hæmatin into pyridine hæmochromogen, and determination of the intensity of the absorption bands of the latter. Elliot and Keilin (*Proc. Roy. Soc.*, B, 1934, **114**, 210) were unable to confirm that these two quantities were always proportional to each other, and so regarded Kuhn's conclusion that peroxidase was a hæmatin derivative as not completely proven. However, in a recent paper in which Keilin and Mann (*Proc. Roy. Soc.*, B, 1937, **122**, 119) compare the peroxidase activity of various preparations, not with the total hæmatin content as estimated by the pyridine-hæmochromogen method, but with a particular fraction determined spectroscopically, exact proportionality is found. The obvious inference is that the preparations employed contain varying amounts of an inactive

hæmatin derivative in addition to the hæmatin-containing enzyme. Keilin and Mann conclude that Kuhn's conclusion was correct, and there would now seem to be no doubt that peroxidase, like catalase, is a derivative of hæmatin very analogous to methæmoglobin. The probability is that it, too, is derived from protoporphyrin though a direct proof of this is still lacking.

There is now considerable evidence that cytochrome *c* (Theorell, *Biochem. Z.*, 1935, **279**, 463; Keilin and Hartree, *Proc. Roy. Soc.*, B, 1937, **122**, 298), one of the respiratory enzymes present in animal tissue, is also a similar methæmoglobin-like derivative of protoporphyrin, though in this case the structure would appear to be slightly more complicated, as the prosthetic group combined with the protein would seem here to be, not a simple oxidised hæmatin, but a compound of the latter with an organic nitrogenous base (*cf.* Zeile, *Z. Physiol. Chem.*, 1935, **236**, 212). It is probable that certain other enzymes will be found to belong to this catalase, peroxidase, cytochrome class. Thus histaminase, the enzyme discovered by Best (*J. Physiol.*, 1929, **67**, 256; 1930, **70**, 349) which, in presence of oxygen, inactivates histamine with liberation of ammonia, shows the characteristic reactions of this type of hæmatin derivative. Porphyrin derivatives have long been known to be widely distributed in Nature, and to play a very important rôle in vital processes. Chlorophyll and hæmoglobin both contain the porphyrin skeleton as an essential part of their structure. The fact that it also enters into some of the most widely distributed and most important enzymes, emphasises how indispensable a part this remarkable configuration of atoms plays in the economy of Nature.

GEOLOGY. By G. W. TYRRELL, A.R.C.Sc., D.Sc., The University, Glasgow.

Editors' Note.—Dr. Tyrrell's contribution will appear in the next number. He completed his article before leaving on June 23 for the International Geological Congress at Moscow, but it would appear to have gone astray in the post.

BOTANY. By PROFESSOR E. J. SALISBURY, D.Sc., F.R.S., University College, London.

WEED CONTROL.—Amongst the plants which have of recent years spread with considerable rapidity in this country few have given greater cause for investigation than the Bracken. Some divergence of opinion has been expressed as to the actual rate of spread, some contending that this is normally slow, others that it is rapid. In

an interesting summary of the whole question of Bracken eradication (*Agricultural Progress*, XIV, 29-39, 1937) K. W. Braid points out that the Bracken, when growing in deep soils, has an extensive rhizomatous system that is in three strata. The lowest, about 20 inches deep, may spread at a rate of more than a yard a year. From this arise branches which spread out at a depth of about 9 inches, and from this second tier short horizontal branches are produced, which make but short annual increments in the horizontal direction, and have for their main function the production of fronds. In shallow soil, however, all three tiers of branches may occur in the upper 9 inches of soil. The total amount of rhizome, which contains the food reserves that must be exhausted if eradication by cutting is adopted, has been calculated as up to 40 tons per acre. Cutting by mechanical means costs about 1*s.* 6*d.* to 2*s.* 6*d.* per acre and by hand from 2*s.* 9*d.* to 3*s.* 6*d.* To be effectual, two or three cuts are necessary for the first two years, and once a year for a further period of from two to five years. The entire cost of eradication by mechanical means is probably from 15*s.* to 20*s.* per acre, whilst chemical methods by means of sodium chlorate are still more costly, and no satisfactory biological control has yet been found.

A point of considerable importance raised by Dr. Braid is whether the rapid spread of the bracken during the past half-century may not be the result of the occurrence of seasons favourable to the formation of prothalli and sporelings. If this be true it furnishes another instance, in the economic field, of the ecological importance of extreme conditions rather than the mean climatic state.

A symposium on the biological control of noxious weeds and insects in New Zealand is reported in the *New Zealand Journal of Science and Technology* (XVIII, 7, 579-93, 1936). Dr. Miller here records that there are at least a million acres of land occupied by Bracken, that the annual value of wool is reduced by some £250,000 owing to the burrs of *Acæna*, that Ragwort (*Senecio jacobææ*) is responsible not only for serious losses to cattle farmers, but also in the honey industry, and that the productivity of enormous areas has been greatly reduced by the Blackberry. Biological control methods have been most successful with *Ulex europæus*, for which the seed weevil (*Apion ulicis*) is employed. Experiments with the *Acæna* Saw Fly are promising. The results with the Cinnabar Moth on the Ragwort have been rather disappointing, but there is considerable hope of satisfactory results from the Seed Fly (*Pegomya jacobææ*). The use of the stem boring beetle in the control of the Blackberry has had to be discontinued, owing to the larvæ becoming predatory on Apple and other fruit trees.

ECOLOGY.—In a paper on the physical properties of soil which affect plant nutrition (*Soil Science*, **44**, 23–36, 1937) R. E. Stephenson and C. E. Schuster record a considerable degree of correlation between the quality of the soil aeration and the amount of root development of Walnut Trees. In soils with 10 per cent. to 20 per cent. of pore space at a depth of 10 feet the root length present in the 9 feet to 10 feet horizon was about 10 per cent. of the total root system, whereas in poorly aerated soils the root growth showed but a very slight development below the level of good aeration. Thus with a pore space of only 5–10 per cent. almost no roots were present below 6 feet.

The behaviour of seventeen species of grasses in relation to water loss has been studied by T. B. Paltridge and H. K. C. Mair. The grasses classified as xerophytic on the basis of habitat and behaviour, when they reached the wilted condition, lost up to 75 per cent. of the water they had contained, whereas the wilted condition was attained in the mesophytes when the water residuum was still from 50 per cent. to 75 per cent. Moreover, the rate of water loss at the onset of wilting decreased with the degree of xerophytism of the species. The species regarded as true xerophytes included *Stipa nitida*, *Oxyropsis miliacea*, *Ehrhartia erecta*, and *Agropyron intermedium*; xerophytic-mesophytes included *Festuca rubra* and *Festuca mairei*.

Experiments are reported by D. A. Clee (*Annals of Botany*, **1**, 2, 325, 1937) which tend to show that the succubous arrangement of the leaves in foliose liverworts is more advantageous for water conduction than the incubous arrangement. Plants of *Plagiochila asplenioides* were placed in the normal succubous and in an inverted incubous position, when it was found that the rate of water transport was much more rapid in the former than in the latter.

An ecological study of an area some 18 square miles in extent near Bloemfontein has been published by G. Potts and C. E. Tidmarsh. The area is an elevated island of Karroo-like vegetation surrounded by bunch-grass plains. The rainfall exhibits a range of from 9 to 17 inches during the summer months, distributed over some 40 to 60 days, and a winter rainfall of from 1.5 to 6 inches with between 5 and 18 days of rain. The temperature exhibits marked extremes, ranging from a minimum of 14.4° F. to over 97° F. Five scrub associations, three bush associations and one grassland association are distinguished. Interesting data are furnished regarding the climatic conditions on valley slopes facing north and south respectively. The sunny northern exposure is characterised by scrub and the southern aspects by the presence of

bush. This is attributed to the indirect effect of climatic conditions, resulting in a deeper soil with more humus on the southern slopes. On the north slope the soil temperatures at a depth of three inches in the summer ranged from 18° C. in the morning to 33° C. at 3 p.m., compared with temperatures of 13° C. to 18° C. on the southern slopes. In winter the northern slopes showed a range from 8 to 24° C. and the southern from nearly zero to 3° C. The relative humidity in summer falls to 42 per cent. on the north slope and to 50 per cent. on the south. It is concluded that the rapid erosion on the north aspect, due to the climatic extremes and greater downwash, has led to the accumulation of a deeper soil on the southern slopes and thus to a more advanced phase of vegetation (*J. S. Afr. Bot.*, pp. 51-92, 1937).

MORPHOLOGY.—A further contribution by A. W. Hill regarding the methods of germination of seeds with a stony endocarp appears in the April number of the *Annals of Botany* (New Series, 1, 2, 239-56, 1937). This includes a summary of all the types investigated which are placed in four major groups. Group I, represented by *Sideroxylon*, exhibits an irregular rupture of the endocarp. Group II, represented by the unilocular *Prunus* and *Juglans*, and the multilocular *Antrocaryon*, *Chærospondias*, and *Allospodias*, exhibits splitting of the loculus, or loculi, into halves. In Group III, the endocarp throws off shutters or flanges; one in *Nyssa*, two or more in *Cornus*, *Davidia* and *Canarium*, where part of the side of the seed cavity forms the shutter, and in *Panda*, *Tectoma*, *Saccoglottis*, etc., where the whole side is thrown off. In Group IV the endocarp opens by lids or caps, which are either simple, as in *Cocos* and *Hyphaene*, or split into two, as in *Pseudospondias*, or are of the nature of stoppers as in *Bertholettia*, *Lecythis*, etc.

In the same journal Mrs. Arber discusses the much debated question of the nature of the Amaryllidaceous corona, from the anatomical standpoint. The stipules of the *Pancreatiæ* are shown to be non-vascular, and, where fused to form a cup from which the stamens arise, are evidently of staminal origin and also non-vascular. The corona of *Narcissus* and its allies is, however, held to be of a different nature, since it is traversed by numerous vascular bundles. These are orientated so that their xylems are towards those of the perianth segments, of which they are probably to be regarded as enations.

In view of the derivation of the uniovulate achene from the multiovulate follicle in the *Ranunculaceæ*, it is of interest to note evidence of the same evolutionary tendency in the related Family of the *Menispermaceæ*. A. C. Joshi (*Proc. Indian Acad. Sci.*, V, 2, 57, 1937) describes the derivation of the single-seeded achenes of

Cocculus villosus by abortion of one of the two ovules contained in each carpel when young. The ovary, though usually consisting of three free carpels, frequently contains a fourth which aborts. The functional upper ovule is amphitropous at first, becoming campylo-tropous later, and consists of two integuments, a nucellus with a small epidermal cap and an embryo-sac of the normal type.

ZOOLOGY. By EMERITUS PROFESSOR W. GARSTANG, M.A., D.Sc.; G. R. de BEER, M.A., D.Sc., and J. A. MOY-THOMAS, M.A., The University, Oxford.

O. DUBOSCQ and O. Tuzet (*C. R., Paris*, 197, 1933, and 200, 1935) have described and figured a remarkable stage in the development of calcareous Sponges (*Sycon* and *Grantia*) which precedes the formation of the Amphiblastula larva. It has long been known in these forms that the embryonic stage which follows cleavage (here called "Pseudoblastula," or stage A) is orientated in the maternal body with its vegetative pole of granular cells (usually eight) next a radial chamber, and its animal pole of numerous columnar cells (ultimately flagellate) away from it. Later, when the young Amphiblastula is fully constituted, with flagellate columnar cells at one pole and numerous granular cells, half invaginated, at the other, the embryo appears to have undergone a rotation, since the flagellate pole is now next the radial chamber and the granular pole away from it (the "Pseudogastrula" or stage B). It has been universally assumed that the flagella arise directly from the external face of the columnar cells. Both assumptions are now shown to be wrong. There is no rotation of the embryo, and, *mirabile dictu*, the flagella arise in stage A as internal structures within the Pseudoblastula cavity. How then do the granular cells, which were proximal as regards the radial chamber, become distal and how do the internal flagella of the embryo become the external flagella of the larva?

Owing to the initial orientation of the embryo these internal flagella of the columnar cells naturally point towards the radial chamber of the mother from the outset. Their tips frequently protrude from the embryonic cavity through the pore in the middle of the granular cells, which has persisted unclosed through all the stages of cleavage. Stage A, in fact, gives rise to stage B by a simple but complete reversal of surfaces. The cleavage pore dilates, converting the disk of granular cells into a ring. The internal surface of the flagellated hemisphere then rises up like a cone, and proceeds to "loop the loop" by protruding through the gaping ring of granular cells, while the latter continues to slip backwards over the flagellated cone until the process of inversion is complete. The

ring of granular cells then contracts on the distal side of the embryo and closes up. The result is a young Amphiblastula. It has been derived from the Pseudoblastula by turning literally inside out.

For forty years we have been satisfied that Sponges, by reversing their larval layers at the metamorphosis, must be removed from the Coelenterates and regarded as a separate tribe of Metazoa, whether as "Parazoa" (i.e. offside animals) or "Enantiozoa" (i.e. inside-out animals). This newly discovered reversal of the embryonic surfaces may seem at first sight to cancel out the other, and to re-open a closed controversy. The French authors indeed are clearly inclined to treat the flagellated layer of Sponges as true endoderm. But the objections to this view are insuperable. "Endoderm" is a secondary derivative at the vegetative pole of an embryo. So also are the granular cells of a Sponge embryo. Its flagellate cells on the other hand are primary: they are constituted at the animal pole, and, in Ascons at any rate, give rise to the granular cells by secondary transformations (Minchin). No acrobatics of Sycon embryos can alter these fundamental facts.

Moreover, the early development of the Sycons is definitely foetal, a ready cause of developmental vagaries. The embryo is enclosed in a cellular "placental membrane," which conveys food-materials from the maternal collar-cells to the primary granular cells of the embryo (Dendy, Gatenby). Duboscq and Tuzet's own figures show a conspicuous enlargement of the placental cells where they overlie the granular disk of the embryo. The latter, in stage A, becomes in fact a purely trophic organ, accelerating the formation of flagellate cells, but, by the very fact of its specialisation, retarding the formation of dermo-skeletal cells—its primary function in other Sponges. It seems reasonable, therefore, to regard the subsequent inversion of surfaces as an adaptive reaction. It brings the animal, locomotive, pole once more to the front, ready to burst into the radial chamber, and carries the specialised trophic cells to the rear, where they appear to be quickly invaginated and divided up (possibly representing Minchin's "archæocytes"), while a new generation of granular cells proceeds to build up the belated store of dermo-skeletal cells, which constitute the posterior, vegetative, half of the ripe Amphiblastula.

J. E. Smith (*Phil. Trans.*, B, 227, 1937, 117-73) has given a thorough and well-illustrated histological account of the nervous system of *Asterias (Marthasterias) glacialis*, revising previous descriptions, and making at least a partial approach towards a synthesis of morphological findings and experimental studies of starfish behaviour. The finer structure of the radial cords and nerve-

ring is particularly well set out, and important conclusions are drawn from its stratification. Special relations are indicated between the more superficial multipolar cells and the incoming twigs of sensory fibres, and between the bipolar cells and the regular disposition of through fibres along speedway tracks in the deeper layers. Smith makes the outstanding discovery of a new system of "lateral motor nerves," segmentally disposed on each side of the arms. They seem to supply all the dermal muscles of the arms, as well as the muscles ("lateral transverse") which connect the ambulacral with the adambulacral ossicles. The nerves have a well-defined origin in paired segmental thickenings of the ectodermal plexus outside the rows of tube-feet, opposite the intervals between the ossicles mentioned. From these bases the nerves, after penetrating the connective tissue and giving off twigs to the lateral transverse muscles, pass upwards between adjacent segments of these muscles, and freely cross the ventro-lateral corners of the coelom towards its lateral wall. They pierce this, and then resolve themselves into a tenuous sheet of subepithelial fibrils which continue their upward course beneath the coelomic epithelium over the whole of its lateral and aboral extent. Cuénot's "apical nerve" is a local condensation of the coelomic fibrils in relation to a special thickening of the longitudinal muscles in the apical zone. Smith finds lateral nerves similarly constituted in all other types of starfish examined, so that they must be regarded as a characteristic element of the Asteroid nervous system.

Lange's nerves, which have so long been the only element in the "hyponeural" or coelomic system, apparently supply only the inferior transverse ambulacral muscles (*i.e.* the adductors). They are believed to be connected with the sensory system by strands on their outer sides which run into them from the outer angles of the radial cords. Thus the sharp separation between ectoneural sensory and hyponeural motor systems has been partly, at any rate, bridged. "The disposition of the motor centres," says Smith, "is such as to suggest that stimuli perceived by the *aboral* surface of the starfish arm will be conveyed as impulses through the *lateral motor nerves*, while response to stimulation of the *oral* surface will be effected through the *sensory-motor reflexes of the tube feet*, and through *Lange's nerve* via the radial nerve cord." (Two misprints—*muscles* for *ossicles*—need correction in the last few lines of pp. 151 and 156.)

R. Dennell (*Trans. Roy. Soc., Edin.*, LIX, 1937, 57-78) concludes a study of Peracarid feeding mechanisms with an account of that of the Tanaid *Apsaudea talpa*, and, as promised in his previous

paper on the Cumacean *Diastylis* (*ibid.*, LVIII, 1934, 125-42), discusses the evolution of both types from Proto-mysid ancestors. The subject, bristling with detail, requires the greatest pains in presentation, and both accounts are exceptionally well arranged, expressed, and illustrated. The Cumacea are shown to be essentially Proto-mysids with a maxillary food-filter, but with all the arrangements of the body profoundly modified by adaptation to a life of semi-immersion in sand. The carapace is practically closed below and behind against the inlet or outlet of water, and both apertures are carried forwards to the head end, which alone projects from the sand when at rest—the inhalant to the oral region, and the exhalant to the tip of the snout by remarkable transformations and adjustments of three pairs of maxillipedes. The feeding current to the filtering plate is feebly served by a reduced and inefficient maxillary pump, its function being taken over by the powerful exhalant branchial currents, which flow in jets over the usual filtering exits, thus sucking water from below through the maxillary filter. These currents are set up and maintained by up-and-down movements of the epipodite of the first maxillipede, which is enormously enlarged as a horizontal valvular septum in the carapace cavity, separating a dorsal exhalant from a ventral inhalant chamber.

In *Apeudes* also, though in a very different way, the respiratory currents in the reduced carapace chamber are set up by peculiar movements of an enlarged epipodite, and there is a corresponding relation to the exits from the filtering chamber, but here it is the inhalant current which draws part of its supplies from these exits, thus inducing a flow through the maxillary filter. Maxillary movements assist, but the combing arrangements are ineffective, and the creatures rely almost entirely on raptorial methods for their nutrition.

As contributions to bionomics these papers are most illuminating, but it is not easy to see how they throw light on "the steps by which the *higher* Peracarida may have been derived," the avowed object of the author's researches.

A series of important works has been devoted to the study of embryonic processes and movements during gastrulation. The conditions in *Scyllium canicula* have been studied by G. Vandebroek (*Arch. Biol. Paris*, 47, 1936, 499), who draws attention to the fact that under the heading of gastrulation, many different events are included, such as the formation of a two-layered sac and the segregation of the future germ-layers. But in many cases gastrulation produces a ready-made three-layered sac, and some organ-forming regions are demarcated and individualised without being invaginated.

Vandebroek therefore proposes to define gastrulation as "the translation of the endoderm beneath the ectoderm."

Three groups of Vertebrates have been studied in the same sense by J. Pasteels, viz. Teleostei (*Arch. Biol. Paris*, **47**, 1936, 205), Chelonia (*ibid.*, **48**, 1937, 105), and Aves (*ibid.*, 381). Of the numerous and important conclusions to which his work has led, it must suffice to state that all mesoderm is "peristomial," i.e. the distinction formerly made between "peristomial" and "gastral" mesoderm is unreal; the so-called "archenteric canal" of reptiles is bounded by notochord and mesoderm; the endoderm of birds arises by multipolar immigration; the blastoderm varies in its form (open or closed = primitive streak) but is constant in its (invaginato) function; the "germ-layer" is not a morphological unit, but a dynamic "unit of manœuvre."

In a study of the effects of exoplastic organiser-grafts, J. Holtfreter (*Arch. Entw. Mech.*, **134**, 1936, 466) raises the question of homology as applied to inducing agent and tissue induced. Urodele organiser can induce horny teeth in Anuran tissue (which Urodeles never possess): Anuran organiser can induce balancers in Urodele tissue (which Anura never possess). It seems that homology between organs implies genetic affinity between the organisms which induced them rather than between the tissues out of which they have been induced and formed.

P. E. Lindahl, in a paper of capital importance (*Acta Zool. Stockh.*, **17**, 1936, 179), has analysed the phenomena of "animalisation" and "vegetativisation" of the Sea-urchin egg, which, as has been known for some time, may be effected by treatment with lithium and iodine or sulphocyanide ions. His experiments show that the mechanism involved, whereby morphological changes result, concerns local interference with respiration, in addition to other metabolic phenomena, and that the mechanics of echinoderm development may be best interpreted in terms of two antagonistic ("animal-vegetative" and "vegetative-animal") axial gradients. These gradients appear to involve different types of metabolism, and may therefore rest on differential distribution of specific substances.

PALÆONTOLOGY.—Gross (*Senckenbergiana*, 1937) and Stensiö (*Bull. Geol. Inst. Upsala*, **27**, 1937) have given very thorough descriptions of the neurocrania of Devonian Cladodont sharks, and both authors have come to the conclusion that these skulls differ very little from those of the modern Selachii, particularly *Chlamydo-*

Säve-Söderbergh (*Ark. f. Zool.*, **29**, B, 1937) has given a pre-

liminary account of a new type of fish, *Rhynchodipterus elginensis*, Upper Devonian of Scotland. In many ways it resembles the known Dipnoans, and was originally named (though apparently not described) by Traquair *Dipterus elginensis*, but it differs from the others most markedly in the greatly elongated snout, which gives the head a very sturgeon-like appearance, in the absence of the characteristic Dipnoan tooth-plates, and in the possession of ossified centra in the vertebral column.

Romer (*Bull. Mus. Comp. Zool. Harvard*, 82, 1937) has described the brain case of the Carboniferous Crossopterygian *Megalichthys*. It is essentially similar to that of other Crossopterygii, but Romer's phylogenetic conclusions are interesting and provocative. He concludes that the study of the fossil history of fishes leads one to the belief that the early Gnathostome had the visceral arches fused to the neurocranium, and that subsequently they have become free. Such a hypothetical skull would be derived directly from the Ostracoderm type by a shortening of the trabecular region. This shortening would be essential if Allis and De Beer are right in supposing the trabecula cranii to be the skeleton of the first visceral arch, which in the jawless Ostracoderms would still be gill arches.

PHYSICAL ANTHROPOLOGY. By L. H. DUDLEY BUXTON, M.A.,
D.Sc., Exeter College, Oxford.

THE ethnology and physical anthropology of the inhabitants, ancient and modern, of the American continent have been a matter both of popular and scientific interest ever since Bret Harte in his amusing ballad described the meeting of the "Society upon the Stansilow" and parodied the discussions about the Calaveras skull. Dr. Hrdlička long ago put the older discoveries in their right place and thus cleared the air for the work which he and his successors are undertaking at present. In general terms the problems of aboriginal—as opposed to recent immigrant man—in America can be summed up as follows. First, what is the evidence for the existence of fossil man in America of a different type from the modern American Indian?—the actual dating of finds we must obviously leave to the archaeologists—secondly, what are the characters, if they exist, of the Palæo-Amerinds, that is a non-Indian type of population, either ancient or modern? Clearly these two problems are intimately related. Thirdly, the position of the Eskimo, whose remarkable achievements in living under the most uncongenial surroundings appear to be related to his physical form, has been carefully examined. Lastly, the classification of the modern Indian tribes is naturally

a matter of interest, though here we are on more technical grounds.

The first problem has been recently approached by Dr. Albert Ernest Jenks in the monograph *Pleistocene Man in Minnesota*, published by the University of Minnesota Press. Briefly the archæological position of the find is probably "late glacial" and contemporary with the formation of Lake Pelican, and dated in years it has been suggested 20,000 B.C., but estimates in years are so notoriously open to objections that the validity of this statement need not concern us. The physical anthropology is, however, of great interest; here we have a skeleton which, with the evidence at present at our disposal, is dated before the close of the last glaciation. Unfortunately the skeleton is not that of an adult but of a girl of 15, in whom the racial characters are not well developed. The teeth are the main evidence to suggest a difference from modern Indians and they are of a very large size, suggesting an approach in dimensions to Neandertal man, although there is of course no suggestion that this child is Neandertal. We have, in fact, another example of what our recent finds in the Old World are accustoming us to, the discovery of a skeleton of presumed considerable antiquity, but possessing the physical form of modern man. It is hardly necessary to point out the importance of this fact. If we find an ancient skeleton in an old geological bed and the skeleton appears after expert examination to resemble modern man, we are at once inclined to suggest that it is intrusive, but more and more evidence is accumulating to support the theory that man, *Homo sapiens*, goes much farther back than we had supposed, and if Dr. Jenks' find can be thoroughly authenticated, and with the present evidence it looks very suggestive, we shall have another valuable support to the conclusions reached by workers in Europe and the Near East. I need only allude here to the *Swanscombe* finds and Miss Garrod's recent work in Palestine, neither of which have yet been fully published.

The second problem, that of the Palæo-Amerind, has also been advanced recently. It has been held for very many years that the Palæo-Amerinds probably belonged to the same branch of mankind as the Australian aborigines, a theory to which Dr. Haddon lent the great weight of his authority, notably in his book the *Races of Man*. Others have, however, held that possibly some at least of the early people of America, still represented in South America, were rather of Melanesian affinities. It may seem strange to a layman that experts should differ on such a major question as the problem whether a skull should belong to one or other of the great racial

divisions of mankind, the woolly or wavy haired. Whereas, however, the difference in hair form is so distinct, the difference in cranial measurements between representatives of the most primitive of woolly and wavy-haired peoples is in some cases extremely small. Recently however further specimens have appeared. Dr. Hambly has reported that among the collections in the Field Museum in Chicago there are a few skulls from Yucatan, though in bad condition; but judging from the measurements and illustrations they appear to be negroid in type. Mr. Trevor has brought back this spring some skeletons (as yet unpublished) from the Virgin Islands which appear from archaeological evidence to be definitely pre-Columbian. Morphologically there can be little doubt that the skulls are certainly negroid; they might well come from certain parts of Africa or Oceania. The physical anthropologist is in these matters the slave of the archaeologist; if the dating is right, then some form of negro was in America before the coming of the slave trade. Whence he came and how he travelled is a problem as yet untried.

The third question which I put at the beginning of this article is the position of the Eskimo. The question is approached by Dr. Morant in *Biometrika*, XXIX, June 1937 ("Eskimo Craniology based on previously published Measurements"). Dr. Morant uses the coefficient of cranial likeness. He concludes that there is no correlation between geographical position and resemblance based on the coefficient, and suggests that this must be due to migrations. He has evidence of a number of existing types and one extinct type. It may presumably be concluded that the isolated position of the Eskimo has resulted in the formation of small local types. Some of the detailed measurements are of interest. Dr. Morant finds that the Eskimo tend to be extreme among the human race in several characters. First, the length of the skull of the extinct group examined is almost as great as the largest male average recorded for mankind; this is of course associated with the large brain size, a characteristic of these people. Secondly, the narrowness of the nose, whether expressed as absolute breadth or as a percentage of the length, is extreme. This can probably be associated, as Thomson and Buxton have shown, with the coldness of the climate, but at the time their paper was written they were not aware of the extreme narrowness now recorded by Morant. Finally, though the nasal bridge is not particularly flat, the Eskimo possess the flattest nasal skeleton yet recorded.

Turning to the relationship of the Eskimo with other peoples on the grounds of cranial resemblance, Dr. Morant obtains the following series: Modern Chinese—Chalcolithic Chinese—Chukchi—

Western Eskimo—Central Eskimo—Greenland Eskimo. It has generally been suggested that the Chukchi living in the extreme northern tip of the Asiatic continent showed affinities with the Eskimo, and it is interesting to have this point confirmed by Morant's observations. As yet we have no complete link with Europe, a link which might be expected from the close resemblance between the skulls of the Eskimo and the Palæolithic skull from Chancelade, at present a unique specimen.

The distinction of linking up Europe and America anthropologically may possibly fall eventually to the lot of the Anatomical Institute of Helsingfors whose work on the polar and subpolar races of Europe is of extreme interest. The conclusions of several papers may be conveniently taken together. (*Acta Instituti Anatomici Universitatis Helsingfors, edidit Vaino Lassila, VIII.* The individual papers are : Esko K. Näättänen, *Ueber die Anthropologie der Lappen in Suomi*, Niilo Pesonen, *Suomalaisten antropologisista ominaisuuksista*, and the same author, *Anthropologische Untersuchungen an Bewohnern der Landschaft Savo*). The first is an elaborate and extremely carefully documented paper based on observations both on skeletons and living persons. It is clear that the Lapps are remarkable for the extreme breadth of their head and represent in many ways a type among the Polar peoples as extreme on one side as the Eskimo are on the other ; they link up with most of Polar races of the Old World, and it is interesting to note that we have thus two wedges of circumpolar peoples, one in Eurasia, characterised by very broad heads, and another in America, characterised by very long heads and showing affinities with Asiatics in the extreme north-east of that continent and with other peoples farther to the south. The Finns present an equally interesting study. In spite of their linguistic affinities, which connect them with many of the dark, straight-haired peoples of Asia—do we not speak of Finno-Ugrian languages ?—they are physically a fair folk. Pesonen found in Savo that of nearly 600 men and 376 women, 87 per cent. of the men and 83 per cent. of the women had light eyes, 49 per cent. of the men and 47 per cent. of the women blond hair. Although he does not give the colour for the whole of Finland his other measurements suggest that probably if anything the proportion of blonds might be greater. Among the Lapps 31 per cent. of the men have light eyes but only 20 per cent. of the women. The hair appears to be rather differently classified and no comparison can be made. Generally speaking, however, it is clear that this work is of great interest since we must revise our estimates of the Mongoloid peoples if we consider that black hair and brown eyes are a definite characteristic

of these peoples, and there seems no reason to doubt this ; then we must place the Lapps as a mixed race between the Wavy and Straight-haired peoples, while these observations on the Finns seem to confirm the suggestion of other writers based on craniological material that the Finns are racially of Nordic affinities. This abundant and careful material is clearly a most useful approach to what may well be considered a major anthropological problem.

Frank H. Cleaver (*Biometrika*, XXIX, 1937) discusses the human mandible biometrically. He concludes that the method of the coefficient of racial likeness does not lead to satisfactory results when applied to the human mandible. In some instances they show resemblance in type where there is certainly no close racial affinity and sometimes the reverse is the case. His figures are, however, extremely suggestive, and though this point is not raised by the author himself, it becomes clear that the exact technique which the Biometric school have now defined may prove of great value for a study of the mandible from the point of view of factors such as environment which cut across racial classifications. On the other hand, in the same number of *Biometrika* Dr. Woo, in a "Biometric Study of the Human Malar Bone," concludes that while some measurements of this bone are of no value for purposes of classification there are other measurements which are of the same nature as such generally used criteria as skin colour, nasal index, and methods of estimating the flatness of the face and of prognathism, that is characters which tend to be more or less constant within any of the major races but which are of importance when groups within these major races are compared with one another.

The papers so far discussed have been mainly on problems connected with the classification of man. In the *Journal of the Royal Anthropological Institute*, LXVI, 1936, W. E. Le Gros Clark and S. Zuckerman discuss a very different problem, namely "The Endocranial Cast of the Chimpanzee." The question may at first sight seem remote ; it actually has, however, a very practical bearing. It has been suggested that considerable information about the brain of fossil man could be extracted from a study of endocranial casts. The matter had never been tested experimentally and some of us were left to behold with admiration the conclusions which apparently could be drawn from a cast of the interior of an ancient skull ; we admired the brilliance of the deductions, but were often unable to understand how they were obtained. Professor Le Gros Clark and Dr. Zuckerman have now set our minds at rest. They examined the endocranial casts of six chimpanzees and later compared them with the actual brains ; their technique is thoroughly controlled and

somewhat elaborate but it resulted in casts which are probably as good as can be made and certainly better than most which could be made from fossilised remains. They conclude that very little information can be obtained about the grooves on the surface of the chimpanzee's brain from the majority of their casts, with one exception, "but even in this there is no certain trace on the cast of the precise disposition of some important sulci in the brain itself." They criticise on the basis of their observations some of the conclusions which have been reached about the brain of Neandertal man. Finally they discuss in some detail the conclusions reached by Dart in a preliminary note about *Australopithecus*. It will be remembered that Dart's examination of the endocranial cast of this fossil ape (R. A. Dart, *Nature*, Feb. 7, 1927, and *Natural History*, XXVI, No. 3, 1926) led him to believe that the ape possessed certain human characters, which suggested that it occupied an important position in regard to human evolution. After a study of the endocranial casts of the chimpanzee the authors conclude that the furrow which Dart identifies as representing the *sulcus lunatus* exactly resembles both in appearance and position the furrow on the casts caused by the lambdoid suture, and they conclude that apart from the proportions and general contour of the endocranial cast, which they believe would repay a detailed comparative study, "there is nothing to suggest that *Australopithecus* possessed in its cerebral anatomy any features indicative of an approach to a human status." These conclusions based as they are on experimental evidence supported by a rigorous technique should be of the greatest importance in the future study of remains of fossil man or of those of his relations which chance or purposive excavations may bring to light.

NOTES

Fishery Investigations (E. F.)

Although scientific research is of undoubted value to industry and commerce, it is difficult to assess the economic value of individual investigations. For in this matter, as in sport, one is apt to be impressed more by the actual scoring of a "goal" than by the solid work in "mid-field" which leads up to it. Goal-scoring is spectacular and its significance easily comprehended by all, whereas mid-field work, however brilliant and valuable, is by nature more technical and therefore appreciated to the full only by those who are conversant with the finer points of the game.

Fishery research is scoring its goals—it would fail in its purpose if it did not do so—but these are the fruits of much patient and skilful work in many branches of enquiry. Review copies of a number of publications ¹ dealing with recent researches at the Government fisheries laboratories at Lowestoft and Aberdeen bear out this point.

- ¹ F. M. Davis, *An Account of the Fishing Gear of England and Wales*, third edition, Ministry of Agriculture and Fisheries, Fishery Investigations, Ser. II, Vol. XV, No. 2, 1936 (H.M. Stationery Office, 6s. net).
- D. S. Raitt, *The Haddock Stocks of the North-East Atlantic, 1916-1935*, Fishery Board for Scotland, Scientific Investigations, 1936, No. 1 (H.M. Stationery Office, 1s. 6d. net).
- A. Bowman, *Lemon Soles ("Pleuronectes microcephalus")*. *Marking Experiments in Scottish Waters during the Period 1919-1931*, Fishery Board for Scotland, Scientific Investigations, 1935, No. 1 (H.M. Stationery Office, 2s. net).
- S. G. Gibbons, "*Calanus finmarchicus*" and other Copepods in Scottish Waters in 1933, Fishery Board for Scotland, Scientific Investigations, 1936, No. 2 (H.M. Stationery Office, 2s. net).
- R. E. Savage and R. S. Wimpenny, *Phytoplankton and the Herring, Part II, 1933 and 1934*, Ministry of Agriculture and Fisheries, Fishery Investigations, Ser. II, Vol. XV, No. 1, 1936 (H.M. Stationery Office, 4s. 6d. net).
- F. S. Wright, *Report on Investigations into the Condition of certain of the Oyster Beds in the South Wales Sea Fisheries District, June, 1934*, Ministry of Agriculture and Fisheries, Fishery Investigations, Ser. II, Vol. XIV, No. 5, 1935 (H.M. Stationery Office, 2s. net).
- F. S. Wright, *Report on the Maldon (Essex) Periwinkle Fishery*, Ministry of Agriculture and Fisheries, Fishery Investigations, Ser. II, Vol. XIV, No. 6, 1935 (H.M. Stationery Office, 2s. net).

Mr. Davis' most informative *Account of the Fishing Gear of England and Wales*, first published in 1923, now appears in its third edition. This standard work of reference to the construction and use of our country's varied fishing equipment is brought up to date by the complete re-writing of the section which deals with the Vigneron-Dahl Gear—now the most important trawling apparatus. Mr. C. F. Hickling, who has had much first-hand knowledge of the subject, is responsible for this useful addition. An important new chapter deals with the question of modifications of fishing gear, designed to mitigate the ill-effects of the destruction of small unmarketable fish—a question of first-class interest now that Great Britain's fishing is subject to regulations governing the size of mesh which may be used.

Dr. E. S. Raitt reports on the stocks of haddock in the north-east Atlantic and their fluctuations over the twenty-year period 1916–35. He produces sound evidence to show that the haddock in this region exists in a number of geographically separate populations, of which the chief are the haddock of Iceland, of Faroe, and of the North Sea and contiguous waters less than 200 metres' depth. Each of these independent populations is subject to marked fluctuation in the numerical strength of the new broods of young added to the stock yearly. And, of course, this brood fluctuation is followed by rise and fall in the yield of the commercial fisheries a few years later. Thanks to continuous study of the haddock stock of the North Sea, the Scottish Fishery Board has been able to build up a prediction service which issues every year a forecast covering commercial fishing for the next twelve months. The important point which now emerges, however, is that each of the other economically valuable haddock populations has its own (and different) amplitude of brood replenishment. Dr. Raitt, looking into the future, visualises an international prediction service which will be in the position to intimate from year to year the varying prospects for the different fishing areas.

A most profitable method of obtaining information on the life history, habits and migrations of certain fishes, is by liberating living fishes which have been marked with some form of identity disc. The amount of information obtained in this way depends upon (1) a marking disc which is simple to attach, not likely to be subsequently lost or to cause undue inconvenience or damage to the fish, and easily seen by the fisherman who recaptures the fish; (2) the proportion of liberated fish which are recaptured; and (3) the reliability of the information given by the person making the recapture. Dr. A. Bowman gives an instructive account of mark-

ing experiments with the lemon sole in Scottish waters during the period 1919-31. Of a total of 7,799 fish marked and liberated, 1,015 (13 per cent.) were subsequently recaptured. Some fish (the non-migrants) remained more or less stationary within a radius of 30 miles of the place of liberation, whereas others (the migrants) moved considerable distances. Out of the 1,015 recaptured fish, 218 were migrants and 797 non-migrants. Migration is seasonal in character, being more intense from December to March, the rate of migration proving in some cases to be about two miles a day. The migratory course is definitely contranatal, and fish liberated in offshore regions approach the coast. A northward movement of adult lemon soles was established along the east coast of Scotland to the Orkneys and Shetlands, and a westward or south-westward course between these groups of islands. A southerly movement of some fish on the east coast south of Rattray Head was attributed to the presence of an eddy current system on the east Scottish Bight. Of the other interesting facts determined by these experiments it was shown that male lemon soles mature at a smaller size than the females. Males sexually ripe occurred throughout the year, although they were most numerous during the summer months. Ripe females were caught only from March to October, and chiefly from May to August. Furthermore, four definite spawning localities for the lemon sole were established.

A highly important section of fishery research is the study of the "plankton"—the animal and plant life which inhabits the water layers between the surface and the bottom of the sea. Most fishes, during a longer or a shorter part of their lives, depend for food upon certain plankton organisms. The small crustacean *Calanus finmarchicus*, for example, is the most important fish-food constituent of the plankton in Scottish waters. Hence there is good reason for intensive study of its occurrence and distribution, such as is described by Dr. S. G. Gibbons. In England, detailed study of the mass occurrence of plant plankton (the *phytoplankton*) in its relation to fishing has been undertaken. Messrs. Savage and Wimpenny describe the location of enormous patches of diatoms in the southern North Sea, and state that the herring shoals tended to mass against the edges of these patches. The animal part of the plankton (the *zooplankton*) aggregated in a similar manner, though not in the same place as the herring. The diatom patches occurring in the early part of October 1933 clearly delayed the arrival and assembly of the great East Anglian herring shoals. It was also observed that diatom patches are water-borne in a recognisable way, dependent upon the prevailing current-system in

different areas. Knowledge of this kind is of obvious significance to the herring fishers.

Finally, Mr. Wright's papers on the South Wales Oyster Beds and the Maldon (Essex) Periwinkle Fishery are a reminder that continuous investigation of shellfish and their fisheries is a recognised part of organised Government fisheries service. They also illustrate the way in which local administrative committees, anxious to maintain the prosperity of the fisheries under their charge, may be materially assisted by expert enquiry on the spot. The South Wales Sea Fisheries Committee, for example, had authorised a certain amount of experimental work to be carried out during recent years in an endeavour to increase the local oyster population, and were anxious to know whether their efforts had met with success. The Corporation of Maldon, Essex, is responsible for the administration of the sea fisheries in a part of the estuary of the river Blackwater. During 1930, the Corporation was approached by a deputation of the local fishermen with a request that the bye-law prohibiting the taking of periwinkles otherwise than by hand be rescinded. The Corporation, while wishing to meet the demands of the fishermen so far as possible, desired at the same time to conserve the stock of periwinkles, which provides a number of fishermen and other persons with a fair livelihood, from September to April, when most other forms of fishing are suspended in this region. They therefore applied to the Ministry for information which would assist them in coming to a decision.

The Annual Report of the Calcutta School of Tropical Medicine and the Carmichael Hospital for Tropical Diseases, 1936 (P. J.)

Bt.-Col. R. N. Chopra, the director of the Calcutta School of Tropical Medicine, in his report for 1936 has again to announce the loss of a valuable member of the staff by the death of Lt.-Col. R. Knowles, the professor of protozoology and for some time officiating director of the school. The loss is a severe blow to the institution, following as it does within a year of the death of Lt.-Col. Acton, the professor of bacteriology and pathology.

The report deals with the routine work of the various departments and shortly with the special researches with which they have been concerned during the year. Among these may be mentioned the bacteriophage therapy experiments in connection with cholera. Of 1748 patients, 871 were treated with cholera phage and 877 were not treated with phage, the selection being made by taking alternate admissions, irrespective of age severity or general condition. Both series received the usual routine treatment for cholera, the

phage treated receiving in addition 2 c.cm. doses of cholera phage every four hours ; bacteriological examinations were made on each case on admission, and afterwards once in every 24 hours up to the complete disappearance of symptoms. Cholera phage used for treatment was prepared on freshly isolated agglutinable strains, and it was endeavoured to ensure the presence of all types of cholera phage in each brew.

Taking the gross mortality of the two series—irrespective of the exact nature of the case and the cause of death—the rate was 13·2 per cent. in the phage-treated series and 15·72 per cent. for the controls ; this difference is not statistically significant. Among patients passing vibrios there is a mortality rate of 8·5 per cent. in the phage-treated (467 patients) and 18·06 per cent. (504 patients) in the control series. In a series of patients from whom agglutinable vibrios were recovered the mortality rate was 8·5 per cent. in the phage-treated (400 patients) compared with 20·71 in the non-phage-treated. There were $2\frac{1}{2}$ times as many deaths among the controls as among the phage-treated series. The results show that in patients suffering from cholera, and in whom vibrios can be found, bacteriophage is of definite therapeutic value, and should be given an extensive trial.

Opportunity arose for trying monkey malarial therapy in a number of cases of neuro-syphilis. *P. Knowlesi* causes a well-marked reaction, easily controlled by antimalarial drugs, and is free from many of the disadvantages of treatment with ordinary benign tertian infection transmitted by mosquitoes or by the injection of infected blood.

The final analysis of last year's investigation of anæmia in 100 coolies shows that, with few exceptions, the anæmia was of the microcytic hypochromic type and in no instance of the pernicious type. The response to treatment with large doses of iron in 39 out of 40 cases pointed to an iron deficiency anæmia, and the deficiency was possibly in the diet, but this was richer in iron than that of many non-anæmic communities ; the absence of milk and the low fat consumption is the striking feature of the dietary of these coolies. The water of the district contains a large quantity of iron, but this is in ferric state. Fractional gastric analysis in 87 cases showed the presence of free hydrochloric acid in 80 without administration of histamine. The incidence of achlorhydria is lower than occurs in the normal population, and the possibility that the iron deficiency is due to failure of absorption on this account is ruled out.

In nearly every case hookworm infection was present. An examination of samples of stools from a normal coolie population

shows about 100 per cent. infection rate, but only about 14 per cent. with heavy infection (10,000 eggs per grm.). It was not possible to correlate the degree of anæmia with the severity of the infection as demonstrated by the egg counts. It is certain that ankylostomiasis is the chief causal factor of the anæmia, but, as a normal hæmoglobin level is not incompatible with a heavy hookworm infection, there is probably some other factor that determines why anæmia occurs in some cases and not in others. Malaria is also an associated factor, the spleen being enlarged in one-third of the cases, but there is no correlation between the size of the spleen and the degree of the anæmia. It has been shown that diet deficiency is not an important factor, but there is some unknown factor limiting the final Hb level, and the level is not that of the city-dwelling Indian.

The main factor in hookworm anæmia is the loss of blood and all its constituents; iron treatment will restore to a certain level, but not back to normal. Antihelminthic treatment alone will not effect a cure, and almost maximal improvement can be obtained without any antihelminthic treatment.

Investigation of anæmia amongst pregnant women in Assam showed that there is no sharp line of distinction between anæmic and normal women; the mean Hb of a series (228 women) is 9.22 grm., the normal coolie women Hb is 10.03 grm., and 6.875 grm. is regarded as the lowest level for normality. The Hb state of the general female population is low, but there does not seem to be any physiological lowering of the Hb level in pregnancy as is noted in other countries, nor is there evidence of any progressive Hb deterioration through the course of the pregnancy.

There is a long report with many exhaustive tables from the Pasteur institute section which deserves careful study, but which space unfortunately does not permit to be included in this review. It is with the same regret that this note must forgo consideration of the sections dealing with skin diseases, leprosy, filarial infection, diabetes, public health, etc.

The School of Tropical Medicine in Calcutta is indeed to be congratulated on the valuable and interesting results of the year's work.

"The Blood Groups of the Bantu of Southern Africa" ¹ (P. J.)

In this interesting paper the author considers the application of blood groups to ethnology. The material was obtained from

¹ Ronald Elsdon-Dew, Publications of the South African Institute for Medical Research, No. XXXIX, Vol. VII, pp. 217-300.

5000 Bantu of southern Africa. It seems that the classification of Bantu tribes is quite arbitrary ; they comprise many ethnic sections. However, in spite of this, 500 individuals of each of 10 tribes were submitted to blood-grouping reactions, and the results are set out in a table. As might be expected, these show marked differences between the tribes ; e.g. group " O " varies from 42.6 per cent. in the Mpondo to 64.2 per cent. in the Tchopi, and there are similar differences for the other blood groups.

The technique employed was carefully considered with regard to sensitivity and dilution of the serum and cells, the influence of temperature, the time taken for the reaction and the effect of interval before using the reagents, attention to the causes and exclusion of pseudo-agglutination, etc. The international classification of the groups (O, A, B, AB) was used ; no investigation was made for the M and N groups. Bernstein's multiple allelomorph theory formed the basis of the arguments in the ethnological portions of the paper. The author has devised a chart for the presentation of blood groupings which has advantages over the charts of Hirsfeld and others in showing the positions of p , q , r , as related to an " origen " ; plotted as circular areas the radius for each circle is taken as the greatest deviation, whether it be p , q , or r . Hirsfeld's biochemical index $\frac{A + AB}{B + AB}$ is not applicable, as it takes no account of group " O."

The author contends that the black race, like the North American Indians long separated from the rest of mankind, originally had no agglutinogens ; he suggests a prehistory of Africa based on serological findings and considers that the Bantu are the result of the interaction between the Caucasian races and a primitive black race showing little if any " A " and " B " ; they are serologically more primitive than, but unrelated to, the Bushmen, and it is probable that the Hottentot has had some effect, possibly only in recent times.

This is a fascinating subject for research and is still largely unexplored. We shall look forward to further work from Dr. Elsdon-Dew.

A New Journal of Microscopy¹ (F. W. J.)

As " a monthly journal devoted to the science and recreation of microscopy " this periodical is an attempt to fill a gap in the literature on microscopy.

¹ *The Microscope : The British Journal of Microscopy and Photomicrography*, Vol. I, No. 1, August 1937. [Pp. x + 28.] (London : Arthur Barron, Ltd. 1s. per month or 12s. yearly.)

The contents of the first number cater for a wide range of tastes. The technique for mounting filamentous algæ by the lacto-phenol method is dealt with at length, and there are articles on the cleaning of diatom frustules for mounting, and on marine diatoms. A serial contribution, "The Microscope and Entomology," deals in this first issue with the house-fly, while an account of *Vorticella* occupies another article. Photomicrography receives its share of attention, with articles on stereoscopic photomicrography and on the accurate recording of colour; there are also details of the construction of a simple drawing apparatus for use with the microscope. The issue is illustrated by some excellent photomicrographs.

Some of the contributions are not as free from misleading or inaccurate statements as might be expected in a journal of this type. For example, "These spiracles are the insect's lungs . . .", and in reference to *Vorticella*, ". . . such vacuoles [food vacuoles] circulate in the inner substance, known as the 'protoplasm.'". There is, moreover, little excuse for the adoption, at times, of the usual newspaper practice of beginning generic names with a small letter.

Despite such criticism, it is to be hoped that this new publication meets with success. There is room for a journal for the amateur microscopist, and there seems to be little doubt that it is the editorial policy to produce a periodical of this type.

Miscellanea

The Right Hon. the Earl of Athlone has been elected a fellow of the Royal Society under the statute which permits the election of persons "who have rendered conspicuous service to the cause of science or are such that their election would be of signal benefit to the Society." Three foreign members have been elected, namely: Prof. August Krogh, the physiologist, of Copenhagen; Prof. Otto Meyerhof, the physiologist, of Heidelberg; and Prof. H. N. Russell, the astronomer, of Princeton University.

The first award of the Johannes Schmidt medal has been made to Mr. H. G. Maurice, president of the International Council for the Exploration of the Sea and fisheries secretary in the Ministry of Agriculture and Fisheries.

Dr. B. Lyot of France, Prof. J. H. Oort of Holland and Prof. Shajn of Russia have been elected associates of the Royal Astronomical Society.

Dr. F. F. Blackman has been awarded the gold medal of the Linnean Society, and Dr. C. F. A. Pantin has received the Trail award. Dr. R. Dohrn of Naples, Dr. H. A. Spoehr of California

and Prof. E. Anderson of Stockholm have been elected foreign members of the Society.

Prof. W. G. Cady of Connecticut has been awarded the Duddell medal by the Physical Society for his work on piezo-electric oscillators as standards of frequency.

Prof. F. G. Donnan and Sir Napier Shaw received the honorary degree of doctor of science at the centenary celebrations of the University of Athens, and Mr. C. C. Paterson, director of the General Electric Co. research laboratory at Wembley, has had the same degree conferred upon him by the University of Birmingham.

Prof. R. M. Gordon, professor of tropical diseases in the University of Liverpool, has been awarded the Chalmers gold medal of the Royal Society of Tropical Medicine and Hygiene.

We have noted with regret the announcement of the death of the following well-known men of science during the past quarter : Prof. Alfred Adler, psychologist ; Prof. Henry E. Armstrong, F.R.S., chemist ; Dr. J. W. Capstick of Trinity College, Cambridge, physicist ; Prof. E. B. Elliott, F.R.S., emeritus professor of pure mathematics in the University of Oxford ; Mr. J. H. Field, C.S.I., formerly director of observatories, India ; Prof. A. W. Gibb, emeritus professor of geology in the University of Aberdeen ; Prof. Albert Griffiths, formerly professor of physics in Birkbeck College ; Major J. H. Hardcastle, ballistics expert ; Prof. H. H. Jeffcott, secretary to the Institution of Civil Engineers ; Prof. D. M. Lewis of Aberystwyth, physicist ; Prof. A. R. Ling, formerly professor of brewing in the University of Birmingham ; the Marchese Marconi ; Sir David Masson, F.R.S., emeritus professor of chemistry in the University of Melbourne ; Prof. T. Mather, F.R.S., emeritus professor of electrical engineering in the City and Guilds College ; Prof. J. W. Michaelson of the Department of Natural History, Hamburg Museum ; Mr. R. J. Mitchell, C.B.E., chief engineer and designer Supermarine Aviation Company ; Prof. W. Natanson of Cracow, physicist ; Prof. S. C. B. Pennington of Reading University, agriculturalist ; Prof. A. G. Perkin, F.R.S., emeritus professor of Colour Chemistry and Dyeing in the University of Leeds ; Miss Dorothy Sladden, zoologist ; Prof. J. L. Stocks, vice-chancellor of the University of Liverpool ; Prof. J. Walther, emeritus professor of geology and palæontology in the University of Halle.

Sir Robert Pickard, director of the British Cotton Research Association, has been elected vice-chancellor of the University of London.

Prof. P. M. S. Blackett has been appointed to succeed Prof. W. L. Bragg as Langworthy professor of physics in the University of Manchester.

Prof. S. Sugden has been appointed professor of chemistry in University College, London.

Mr. C. E. Jones has been appointed registrar of the Indian Institute of Science and Mr. R. B. B. Venkatesachar interim director for a period of one year, their salaries being 1250 rupees and 1000 rupees per month respectively. Sir C. V. Raman has accepted the post of professor of physics in the Institute at a salary of 2500 rupees per month.

The A. E. Hills chemical laboratories in the University of Birmingham were formally opened in July. The buildings cost £50,000 and the donor, Mr. A. E. Hills, has provided, in addition, £25,000 for post-graduate scholarships.

The Earl of Rothes has accepted the appointment of Chairman of the Governors of Faraday House Electrical Engineering College, in succession to the late Lord Castletown.

The latest issue of the quarterly *Bulletin of the Imperial Institute* (obtainable from the Institute, price 2s. 9d. post free) records the results of examination of a large number of samples of Tung seed and oil received from various countries of the Empire where the trees are the subject of experimental plantings, and also an investigation of camel hides from British Somaliland. The articles include a paper by the Director, Sir Harry Lindsay, on the Imperial Institute's Services to South Africa, one on oil palms in the Belgian Congo by Prof. Ed. Le Plae, and another describing the tantalite deposits of South-Western Uganda. The "Notes" section covers a very wide range of topics, including a résumé of the Report of the Committee appointed to enquire into the grading and marketing of wattle bark in South Africa; the experimental cultivation of oil-yielding plants in the Irish Free State; cacao shell as a foodstuff for cattle; the effect of sarcoptic mange in goats on the leather produced from affected skins; the occurrence of selenium in soils and crops; gold recovery by dry-blowing in Tanganyika, a method which enables work on the detrital deposits to be continued in the dry season; the geology and mines of the Gwanda Mine Belt in Southern Rhodesia; an interesting and important discovery of stanniferous ironstone in Johore; a new process for the production of alumina and recent developments in the production of aluminium;

mud fluids for petroleum drilling ; the use of rare earths in the coloration and decolorising of glass, etc.

One Note contains a brief account of the radium deposits discovered by Gilbert LaBine at a point to the north-west of Echo Bay, Great Bear Lake, in May 1930. The locality is only 40 miles south of the Arctic circle and, with the exception of the timber obtained locally and the oil fuel brought by water from Fort Norman, 245 miles away, all the supplies for the plant and the 100 employees have to be transported by water from the railhead at Waterways, Alberta, a distance of 1375 miles. Eldorado Gold Mines Ltd., which works the mine, sends the ore to be processed at Port Hope, Ontario, 3000 miles away. Treatment started with a 17-ton shipment in 1931. In 1936, 22,000 tons were milled and by November in that year a total of 1 oz. (28 grm.) of radium had been obtained. The amount seems small, but it sufficed to halve the world price, and production is increasing, for the Company has contracted to deliver no less than 50 grm. this year.

A Bureau of Human Heredity has been formed for the purpose of collecting as complete a record as possible of current information on human genetics. It is directed by a Council representing medical and scientific bodies in Great Britain and is affiliated to the International Human Heredity Committee. We are asked to state that the Council would be grateful to receive all available material, from Institutions and individuals, which furnishes well-authenticated data on the transmission of human traits of any kind. Pedigrees are particularly desired ; twin studies and statistical researches are also relevant. Research workers and others who desire to retain the sole right of publication (or copyright) are asked to accompany their material with a statement to that effect. Reprints are asked for and also details of pedigrees which have been collected for the purposes of a research and not published in full. The chairman of the Council is Prof. R. Ruggles-Gates, and the address 115, Gower Street, London, W.C.1.

It is stated in the *Report of the Food Investigation Board* for the year 1936 that the results of the investigations carried out at the Ditton Laboratory during the last few years show that the pear responds even more favourably than the apple to gas-storage. In particular it has been found that Conference and William's Bon Chrétien pears can be gas-stored for several months and that after removal from storage the fruit ripens more slowly (thus allowing more time for marketing) than fruit which has not been stored in this way. It is believed that recent horticultural research justifies

a hopeful view of the cultural side of the industry which is quite important, since about £2,000,000 worth of pears are consumed annually in this country, and at present the home-producer supplies only about one-fifth of the demand.

The third *Report of the Academic Assistance Council* states that, for legal reasons, the Council has resolved itself into a company to be known as the Society for the Protection of Science and Learning, limited by guarantee of which the subscribers become members. The object of the Society remains as before, to assist "university teachers and investigators of whatever country who, on grounds of religion, political opinion or 'race' are unable to carry on their work in their own country." The last four words are perhaps unfortunate even though their inclusion at the present time is immaterial. The scope of the Society's activity is increasing, for in addition to the help it is giving to refugees from Germany it has received appeals on behalf of scholars from Russia, Italy, Portugal and Spain. Everyone in the academic world is sympathetic towards the work which is being done, the sole adverse criticism arising from a fear that the activities of the Society may affect the careers of our own people. Permanent places have been found in Great Britain for 101 refugees and 127 are placed temporarily. The total is not large in comparison with the number of persons employed in the Universities and University Colleges alone, and one may presume that in some cases, perhaps in many, the permanent employment of these foreign scholars has not resulted in the displacement of native workers or in the frustration of their just expectations of advancement. It is to be regretted, therefore, that the Council does not state the position, which at the worst cannot be very alarming, quite clearly. An analysis of the distribution of the scholars placed in Great Britain shows that 22 are at Cambridge, 18 in Oxford, 7 in Manchester, 7 in Edinburgh, 2 in Glasgow and 60 in the Colleges and Hospitals in London, University College heading the London list with 13 and the School of Economics a close second with 11. The Society has an unallocated balance of some £2,600 after provision has been made for all known demands up to July 31, 1938, and at the moment it does not propose to make a public appeal for funds. An appeal will, however, be made when the needs of the future are better known. Meanwhile, contributions will be received very gratefully at the offices of the Society, 6, Gordon Square, London, W.C.1.

The National Union of Teachers has published the very interesting address delivered at its Conference this year by Sir Philip

Hartog under the title *Secondary School Examinations and the Curricula of Secondary Schools*. Sir Philip opened with a discussion of the purpose of secondary school examinations and of the deficiencies of the present system as revealed by the Report of the Investigators of the Secondary School Examinations Council and of the International Institute Examinations Committee, and then put forward some suggestions for reform.

It would seem that he regards these examinations as a test of the utilisable skill possessed by the candidates or of the progress they have made to that end while ignoring the fact that success in the examination as a whole implies not only the possession of some degree of knowledge and intelligence but also a capacity for learning and possibly for hard work, which is not entirely of negligible importance. The discrepancies in examiners' marks are disconcerting especially when it is remembered that the scripts were marked after the examinations and so presumably received more detailed consideration than would be possible in the examination itself. Differences in the percentages of passes, credits and distinctions awarded by different examiners (or by the same examiner on different occasions) marking the same border-line scripts are not very impressive, since it is often by no means certain on which side of the border a border-line script should be placed, but differences in the average mark awarded by different groups of examiners for the same scripts need explanation. They may arise in part from differences in the standards which have developed in the different Boards and in part from difficulties of assessment inherent either in the subject of the examination or in the type of question set.

The proposals for reform include the abolition of the system which requires a candidate to select his subjects in particular ways from definite groups, the issue of certificates showing the actual performance of the candidates in terms of a scale of adjectives, and the removal of certain subjects, *e.g.* History, English Literature and General Science, from the examination, providing at the same time for their compulsory inclusion in the curriculum. As an appendix to his address Sir Philip quotes a speech made by Mr. C. L. Bryant of Harrow in 1930. Here stress was laid on the undesirability of forcing the curricula of the school examination on pupils whose abilities do not fit them for it, and it is surely on these lines that progress may best be made.

The Cambridge University Press has published a little book by Lord Rutherford bearing the title *The Newer Alchemy*, based on the Henry Sidgwick Memorial Lecture delivered at Newnham

College, Cambridge, in November last (pp. viii + 67, with 8 figures and 13 plates, 3s. 6d. net). It contains an account of the phenomena of the transmutation of the elements written with the clarity and simplicity which characterises all its author's expositions. It will be read with enjoyment by all those who know or who desire to know something of the outstanding achievement of post-war experimental physics.

ESSAY REVIEWS

SCIENCE AND TRUTH. By H. DINGLE, D.I.C., A.R.C.S., D.Sc., Assistant Professor of Physics at the Imperial College of Science and Technology. Being a Review of **The Scientist in Action: A Scientific Study of his Methods**, by WILLIAM H. GEORGE, M.Sc., Ph.D., F.Inst.P. [Pp. 355, with 31 figures.] (London: Williams & Norgate, Ltd., 1936. 10s. 6d. net.)

THIS book is a "scientific study" of "the scientist in action." The writer is "concerned always with what research workers can be observed to do." It is "taken as basic, that scientific research is a form of human action," i.e. of "anything a man may do, which can, with the current technique, be observed by others using coincidence observation. It follows by definition that speaking, writing, or manipulation of apparatus in a laboratory are forms of action but thinking, believing, or feeling are not." "It is customary to discuss the results of scientific research in terms of the idea of a unique and final kind of knowledge called truth or absolute truth." "The technique of scientific research is then regarded as a means of . . . finding out what things are really and truly like." "The Patterning Theory . . . developed in parts of this book," on the other hand, "starts from the human research worker, and the idea of agreement between human observers is used in place of the idea of Truth." The Patternist "never speaks of one theory being nearer to the truth than is another," for his "primary concern is with what men can be observed to do and not with what they think."

As a result of his inspection the Patternist declares that "scientific research is a form of human action which gives two typical products . . . The first product is facts (judgments of coincidence for coincidence observations) . . . The second kind of product is such arrangements or patterns of facts as scientific classifications, laws, and theories." Taking these two products in turn, we learn that "the facts of science are sense data," but "not all sense data are usable in science." "Coincidence observation is used as a means of separating the sense data usable as basic in science from other sense data," because "an examination of human observation shows that agreement between different observers is readily reached without the use of threats or torture if the different observers are set to judge

coincidences. These elementary human judgments give the nearest to universal agreement that is ever reached, and are called either coincidence observations or facts." But "scientists are not satisfied with facts seen in isolation." Moreover, "more generally it would appear that all sense data come first in wholes and are later analysed into smaller and smaller wholes ending (in scientific observation) with the simple whole consisting of two parts, between which coincidence or the lack thereof is judged." "The term pattern property will . . . refer to any property which is characteristic of a whole, but not of the parts into which the whole may be divided for study." "One of the characteristics of normal human actions is that they fit into or complete or make a pattern." Thus "a scientific explanation is a patterning of facts."

The quotations which make up this statement have been taken from widely scattered sections of Dr. George's book, and the reader may wonder whether, after the violent shuffling to which they have been subjected, they give a true account of his thesis—or, shall we say, a pattern identical with his own. It is to be feared that they do not. I hasten to add, however, that this comes from no desire to misrepresent. On the contrary, I believe that Dr. George would accept the statement without demur, for, not sharing his renunciation of everything but description of behaviour susceptible to coincidence observation, I have ventured to summarise what I think is his actual meaning. The fact that it is not always identical with what he says follows, I should say, from his failure to maintain a consistent attitude and to visualise clearly the prospect before him. He has not succeeded in writing with his eye always on the object, and the matter which he has chosen to discuss is so vital that the failure is serious.

To locate the source of the confusion it is necessary to visualise his problem as clearly as possible. Let us, then, try to form a mental picture of the situation. Here is Dr. George, mounted like a tennis umpire on some eminence above the field of operations of science. He watches what happens and gives an account thereof. He sees scientists working. Their activity is "scientific research" and what they produce is "science." The material on which they work is a "whole" which they analyse into "sense data," and they then select "facts," or "coincidence observations," out of the products of the analysis, and arrange these into other wholes, or "patterns." What they are thinking, why they are so acting, whether their activity is good or evil, beautiful or ugly, true or false, tragic or comic, sacred or secular, he cannot say, because he cannot observe such things by coincidence observation. That is the situa-

tion, for the description of which there is clear textual justification in Dr. George's book. Let us see what it implies.

In the first place, such a view is a confused one because it pictures science as being in the field of operations—a creation of the scientists who are being observed—and also as, in part, a creation of the commentator, Dr. George, for his book is a “scientific study.” We are at once trapped in an infinite regress, from which we cannot escape by refusing, as Dr. George does, to use philosophical terms. He is one of the little fleas on the backs of the big ones, we (his “scientific” critics) are his parasites, and so on *ad infinitum*.

This all-permeating defect of the presentation is very regrettable, because Dr. George's case is fundamentally sound, his book is most timely, and it is excellently written. To use terms which he would probably deprecate, he has seen the light, but it has shone on him so fiercely that he sees nothing of what it illuminates but is conscious only of a uniform whiteness. He is, we think, unanswerable when he maintains that what the scientist does is to arrange certain experiences in a pattern which it is inappropriate to describe as truth, but we can only deplore the veritaphobia with which the realisation of this “truth” afflicts him. For it is impossible to think rationally without the idea of truth being somehow involved. Turn it out of the door, and it flies in at the window. And indeed it is difficult to see what there is in this to cavil at. The window is the place for it: like the light, it has its own proper entrance through which it comes full and pure, while the door, which can at best give it partial admission in the company of unwelcome draughts, is best kept shut. We agree that the scientist is not, in any legitimate sense of the words, “finding out what things are really and truly like,” but is not Dr. George trying to find out what the scientist in action is really and truly like? If so, he is not, according to his own criterion, making a scientific study. If not, we must regard him as merely engaged in “a form of human action,” which we must refrain from valuing and which has in it nothing to mark its superiority to the behaviour of Professor X who describes science as a quest for truth. Dr. George has attempted the impossible: he has tried to describe science without using philosophy. “The point of view taken up in this book,” he says, “is throughout uncompromisingly non-philosophical. . . . As a scientist I cannot use the philosophical ideas of ‘truth’ and ‘validity.’” One who attempts to describe science with that attitude can only do one thing; he can produce, as Dr. George does, a philosophy which is bad.

That is not the whole of the trouble. Referring again to our mental picture of Dr. George as a commentator on the activities in the scientific arena, what we have just said is that he cannot significantly give *scientific* comments if "truth" is inappropriate to science. It is possible (and, we think, necessary) to put this right by admitting that it is fair to ask if his account is true, while denying that it is scientific. We can then proceed to the question—*Is* his account true? In particular, is the idea of truth irrelevant to science itself? Dr. George says yes, and we agree with him that the scientist is not "finding out what things are really and truly like" but simply arranging his experiences. But something equivalent (the word will come in) to truth must be recognised in science itself, or why do we prefer one arrangement to another? To Dr. George a scientific theory is "a policy of action": the Patternist "never speaks of one theory being nearer to the truth than is another." But a "bad" theory can be a policy of action—a stimulant, in fact, to the making of observations which will lead to a "better" one. Dr. George would probably object that a "bad" theory gives an inferior pattern to a "good" one, but what is "inferior"? It cannot be "less complete," because any assembly must be a pattern of some kind. Can it be "less logical"? No, because "the rules of logical thought are regarded as rules of action," so that the policy inciting to most action is (valuation being excluded) automatically the most logical. It might indeed be "less beautiful," because Dr. George admits that the Patternist asks, "Do the facts arranged in that particular way give me æsthetic pleasure?"; but elsewhere he seems to exclude such considerations, and, in any case, what is "æsthetic pleasure" doing in a discussion dedicated to what can be observed by the coincidence method? No; even in science itself, "truth" or "value" must be admitted as a necessary conception, and we are much better occupied in putting it in its proper place than in attempting the impossible task of excluding it altogether.

The unsatisfactory character of Dr. George's view of science is manifested in many ways: one must suffice for illustration—his treatment of the word "existence" as applied, among other things, to the external world. To Dr. George, "the idea of an external world is . . . an hypothesis . . . a patterning device"; it is a convenient form of words for expressing the manner in which coincidence observations are obtained, and since human beings also are necessary for such observations, "the users of the Patterning theory can make no scientific statement whatever about a physical world or a mysterious universe which includes no human beings."

When, therefore, he says later that "the thing called a chair can directly give sense data ; it can form one of the two parts essential for judgment of coincidence," we understand that coincidence observations are the only significant things concerned. But now, since there are sense data other than coincidence observations, how are we to distinguish the two kinds ? We cannot. Coincidence observations are defined in terms of external objects, and external objects are only a verbal expression for talking about coincidence observations, and we can only go round and round the circle. The same difficulty applies to human beings : are they also a verbal expression for indicating universal agreement ? If so, what distinguishes agreement from disagreement ? If not, why assume their "existence" and not that of the "external world" ? Verily, the way of the Patternist is no primrose path.

Yet, notwithstanding many defects which might have been removed had Dr. George meditated for a few more years before publishing his philosophy, his book is welcome, and more than welcome. That its shortcomings should receive chief attention is a consequence of the supreme importance of the purpose at which it aims. Nothing but bare, unvarnished truth is good enough in a description of science, but it is no mean achievement to expose and discredit the untruth that science is an attempt to find out what an external world really is. The manner in which Dr. George does this deserves high praise, and it says much for the positive merits of his book that they justify its appearance in spite of its imperfections. In a brief review it has not been possible to deal with more than the main purpose, but there are many incidental discussions and remarks which deserve more than a passing mention, such as the chapter on the future of experimental research and many of the comments on scientific theories. The numerous and lengthy psychological discussions, on the other hand, we read with mixed feelings. It is impossible not to feel that the questions raised can scarcely be dealt with authoritatively by a crystallographer, but the treatment is often very interesting and suggestive, and it is refreshing to remain in Dr. George's company while he has forgotten his principles. When we enter a discussion of whether sense data come to the scientist in wholes and are mentally analysed, or in units which are mentally synthesised ; or a discussion of theorising in which we learn that the origination of new ideas is an essential part of a theory and must come from an individual mind—we tremble lest Dr. George should suddenly remember that the acquisition of sense data is not revealed to coincidence observation, and that the origination of ideas, which is thinking, is not a form

of action : but no, he goes on with numerous examples from his own experience and that of others, and we realise that he can rise above his creed.

And he is eminently readable. Vivid, precise, epigrammatic, and even grammatical, his sentences convey his meaning—not, of course, without payment, but at the cost of an effort which is delightful, never tedious. If his main thesis is a tissue of errors redeemed by one glorious inspiration of rectitude, his writing is a uniform excellence slightly specked with mud. An appreciable part of the cost of printing might have been saved by the avoidance of such phrases as “mental concept” and “a creed of thought” (what other concepts and creeds are there?), and when we encounter a quotation from Faraday for the third time before reaching p. 40 we feel that coincidence observation has unduly triumphed over pattern. But such blemishes are conspicuous only against the general rightness of the whole. No one who, in this mad rush of doing things, believes it is worth while to know what is being done, can fail to be interested and benefited by Dr. George's book. It is as yet almost, if not quite, the only book of its kind to be obtained.

OCEAN FAUNAS. By R. S. WIMPENNY, M.Sc., Fisheries Laboratory, Lowestoft. Being a Review of *Tiergeographie des Meeres*, by SVEN EKMAN. [Pp. xii + 542, with 244 figures.] (Leipzig: Akademische Verlagsgesellschaft m.b.H., 1935. RM. 30.—, paper covers; RM. 32.—, bound.)

A CONSIDERATION of the observations bearing on animal distribution in the sea shows that, while incomparably the richest fauna and the subject of many special monographs in the last thirty or forty years, the littoral fauna has not yet been the subject of any general account. In supplying this deficiency Professor Ekman has produced a work on the animal geography of the sea which is a first effort to deal with the subject on such a scale.

In a short introductory section, the author gives to the science of animal geography the aim of synthesising the history of the animal world. The methods used fall into two chief divisions. First, the taxonomic study and registration of the fauna, and second the study of causal animal geography. This causality may, he suggests, be studied (*a*) from a taxonomic point of view, (*b*) in the light of phylogeny and ontogeny using the palæontological record, and finally (*c*) by the help of ecology and its fundamental physiology. In the case of (*a*) we may seek to find the specific composition for the fauna of a certain habitat in order to find how this composition was attained. While the zoo-geographic value of a species may be

said to be broadly related to its taxonomic position, this research may be helped in several ways by the phylogenetic method suggested in (b). For instance, a given area may be better characterised by a species-group which is phylogenetically homogeneous within its genus than when this is not the case. Moreover, the importance of a species-group to animal geography grows in proportion to what is known about the group that is systematically nearest to it. Finally, species, genera and families acquire increasing value in relation to the degree to which they are endemic. The ecological explanation (c) deals with communities of various sizes treated as entities when dealing with their spread, survival and environment. The sort of question raised by the ecological outlook is "to what animal community does this fauna belong, and how did this community arise?" Instances of small and large communities in this sense are those found on special grades of sea bottom in the North Sea, and on the other hand the whole fauna that swims or floats in the sea—the pelagic community. Another interesting example quoted by Ekman is the coral reef. Here, he says, we have an ecological entity which remains the same whether the coral organisms which form it are of one group of species or another.

In a short concluding passage at the end of the book, it is pointed out that while the geographic distribution of animals depends upon the physiological characteristics of the organism and upon the environment, it is also subject to a third factor, the isolation of areas formerly continuous. This latter factor brings about a discontinuous distribution in which may be seen the working of a divergent evolutionary process.

In view of these ideas it is interesting to see how a consideration of the subject matter has been divided. Of 470 pages constituting the body of the work, 331 may be considered as dealing more or less intimately with a littoral fauna occupying a habitat between the shore and a depth of 200–400 metres. Another 156 pages deals with the benthos and a final 85 suffice for the pelagic fauna.

Apart from the fact that the littoral fauna lives in a more complex environment, and may therefore be expected to be differentiated into a greater variety of species and communities, it is a fauna that the author has made the subject of special investigations which give emphasis and authority to the attention paid to it in the book.

The most important of the littoral faunas in respect of the variety of its species is that of the tropical area. Though this habitat contains many forms common to its whole extent, it may be divided into Indo-West Pacific, East Pacific, West Atlantic and East Atlantic

sub-areas whose species are to a greater or lesser degree characteristic. These sub-areas are divisible into still smaller regions of which the Malay and Caribbean Archipelagoes provide the first and second most diverse faunas in the whole world. Of particular importance to the divisions of the tropical littoral fauna is the deep part of the East Pacific, which, owing to its lack of islands forms a barrier or gap, separating the East Pacific from a fauna common to the Indian Ocean and West Pacific—the Indo-West Pacific division already mentioned.

Though the East Pacific gap is not readily apparent as a barrier, whilst in reality it is very important, the land barrier at Panama between the East Pacific and West Atlantic, though more obvious appears to have been much less important. Many endemic genera—in a group of tropical crabs 33—are common to both areas. In the species, too, a certain but smaller number of endemic forms—for the crabs only 9—are common to both sides. The evidence from the present distribution of this fauna is in conformity with the view most widely held by geologists that the land barrier only dates back to the middle Miocene and that previously there had been a sea connection between the tropical Pacific and Atlantic. The latter area is richer in species than the former and it is thought for this reason that the Atlantic side has been the source of spread.

In all tropical seas where the temperature does not go below 20° C., and where there is little or no fresh water running off from the land, there is found the coral reef community. Where there is mud and fresh water on the tropical seashore there occurs the mangrove community. These two communities are specially dealt with in the book. Their limits clearly cut across those of the other divisions of the tropical littoral fauna, and are obviously made in a different sense. While the physiological nature of this is apparent enough, the difference has not been effectively dealt with, and leaves the reader with a certain amount of confusion.

A chapter devoted to the Mediterranean-Atlantic and Sarmatic (Black and Caspian Sea areas) faunas again emphasises the importance of the geological and palæontological explanation by referring many elements of these faunas to a common source in the Tethys Sea of the Middle Tertiary.

In discussing the littoral fauna north of the tropics it is pointed out that the North Pacific is much richer in species than the North Atlantic. For instance, among the littoral fish species of North America 420 are given as occurring on the Pacific side, whereas the Atlantic has only 190. The Arctic fauna is so intimately related to the cold-temperate, that in the Northern Hemisphere there are

only two main divisions of the littoral fauna, the tropical and the northern. In the Arctic the number of species has fallen away, but along the north coast of Siberia, there appears to be an increase in the number of individuals as the number of species diminishes.

By contrast with the Arctic, the Antarctic littoral fauna (which on account of the distribution of land masses is strictly comparable with the extreme Arctic fauna) is generally wealthier in the number of its species. Ekman considers this greater variety of species explicable by the historic origin of the fauna. Between the Antarctic continent and the tropics a number of regions are distinguished, which, on account of the isolated distribution of the land masses, do not allow of intimate comparison with the northern hemisphere.

The question of "bipolarity" is examined in a chapter of considerable interest in which the author discriminates between the bipolarity of related forms and the bipolarity of parallel phenomena. In the former, the animals of higher latitudes have a nearer taxonomic affinity with each other than with those of lower latitudes. On the other hand, the bipolarity of parallel phenomena shows itself in such things as the increasing individual numbers, size, thinness of shell, change in the way of breeding and a bipolar parallel development of species. It is, therefore, largely an ecological bipolarity.

The benthic deep sea fauna is considered to begin between 200 and 400 metres, and it is conveniently divided into an upper or archibenthic zone above 1000 metres and a lower or benthic abyssal zone below this. It is emphasised, however, that these limits are arbitrary and subject to variation and fusion. For instance, a species that lives in very deep water at the equator may come to live nearer the surface at the poles. The horizontal distribution of the archibenthic fauna resembles that of the littoral, but the benthic abyssal differs, in that the great depths of the ocean form no barrier to it. As a result (although there are many cosmopolitan species) the benthic abyssal fauna can be divided into Indo-Pan-Pacific, Atlantic, Arctic and Antarctic areas.

All those animals which live in the sea clear of the bottom and the shore, and which either drift passively like the plankton, or swim effectively like the nekton, comprise the pelagic fauna.

The plankton organisms may be divided according to size into nanoplankton 5-60 μ , microplankton 60-500 or 1,000 μ , mesoplankton .5 or 1 millimetre to about 1 centimetre, macroplankton one to several centimetres, and megaloplankton creatures of still greater size such as the *Siphonophora*.

Pelagic animals as a whole fall into two great communities, the

upper pelagic fauna and epiplankton extending from the surface to 150 or 200 metres and the bathypelagic lying below that depth.

The epiplankton is divided into cosmopolitan eurythermal, cosmopolitan cold water, warm water, cold water and neritic. The warm water pelagic fauna is on the whole circumtropical, but certain organisms are characteristic of special warm areas in the Atlantic, Indo-Pacific and Mediterranean.

The cold water plankton which lies around the poles contains certain species present at lower latitudes in the underlying cold water which has submerged at the polar fronts. Of the two communities of cold water epiplankton, that of the Antarctic is richer in species than the Arctic. By comparison with the tropics and semi-tropics, the plankton of the cooler seas is richer in numbers but poorer in species.

The divisions of the epiplankton just mentioned are mainly creatures whose whole life history is spent floating or swimming in the open waters of the ocean, but in the case of the neritic plankton which lives over the coastal banks in the neighbourhood of the land, many of its components are only spending a part of their life in this habitat. The neritic fauna compares with the oceanic in the same way that cold and warm water plankton compare—it is richer in numbers but contains fewer species.

Though the bathypelagic fauna is thought to owe some of its species to the benthos, Ekman considers that it has been derived mainly from the upper pelagic fauna. It has strongly marked systematic independence. The circumterrestrial distribution of the bathypelagic fauna is more marked than that of the bathybenthos, but there are parts of it that are somewhat isolated and have thus come to take on especial characteristics as, for instance, the deep water of the Mediterranean which is isolated by the shallow Straits of Gibraltar. There is some evidence of a differential vertical distribution of bathypelagic organisms, though there is not sufficient known about this precisely to define the divisions. It is recalled that Meyer, in discussing the Radiolaria of the *Valdivia* expedition, has made the following division of the water layers.

0-50 m. A well-illuminated zone with "Phaoplankton" and *Collidæ*.

50-400 m. A twilight zone of "Knephoplankton" and *Challengeridæ*.

400-1500 m. A dark zone of "Skotoplankton" and *Tuscaroridæ*.

1500-5000 m. "Nyktoplankton" and *Pharyngellidæ*.

Looking back over pages which represent the condensation of

an enormous amount of observation, one cannot but admire the industry that has marshalled it into chapters. There are, however, certain improvements which, in the eyes of the reviewer, might be made both in the manner of presentation and the matter presented.

In that considerable part of the book dealing mainly with littoral fauna it is not readily to be understood either from the legends at the top of the pages or from the titles of the chapters that this is the case. Titles such as "Mediterranean-Atlantic and Sarmatic" and "Atlantic Boreal" do not immediately imply a littoral fauna to the uninitiated reader. Indeed, in the latter chapter archibenthal species are touched on when it would surely have been less confusing to leave their consideration until those chapters devoted to benthos. Though it is difficult to avoid a certain amount of repetition where a classification of the matter from different aspects tends towards over-lapping, this, one feels, should not extend to a figure of *Meganyc-tiphanes norvegica* which appears on pages 129 and 449. Mistakes in the text must be almost unavoidable in the first edition of a book of this size, but the only one to attract the reviewer's attention was the placing of the Atlantic habitats of *Salmo* s. str. under the heading of Pacific distribution and vice versa in the table on p. 238.

Throughout the book the author has kept well in mind his views on studying the causality of animal geography from a taxonomic and phylogenetic point of view. But he has not summoned the help of "ecology and its fundamental physiology" to anything like the same extent. Where, for instance, a community on one side of the isthmus of Panama has obviously come from the same stock as that on the other, it is natural for the author to accept the inference that the community with the greater number of species represented the source from which the fauna spread. The possibility that, beginning with a homogeneously distributed fauna, the part which has been isolated at a higher temperature might produce a greater variety of form, has not been considered.

In discussing the numerical abundance and specific paucity of the cold water littoral and pelagic fauna, the author points out that these are special cases of a fundamental principle in the study of animal communities ("biozonotik") established by A. Thienemann (*Naturwiss. Wochenschr.* (N.F.), 17, 1918). Thienemann held that the more an environment left the normal and optimum for most organisms, the poorer in species, but the richer in numbers became the animal community. The reviewer is grateful to Professor Ekman for bringing Thienemann's papers to his notice, as in ignorance of this prior work he has made a somewhat similar generalisation as a result of the consideration of fishery statistics (*Report on the*

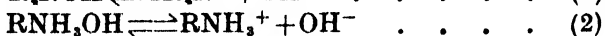
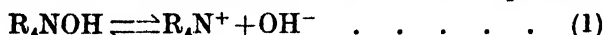
Fisheries of Egypt, 1929). This consideration led to the observation that "the mass of a community of living things becomes greater as its specific composition becomes simpler." As mass appears to depend on food, the optimum for living organisms would appear to be more reasonably stated as lying with the species-poor communities of colder seas rather than with the meagre mass but high differentiation of the tropics.

That Thienemann's generalisation and its interpretation should have been accepted without discussion and that the considerable recent work on the effect of light on the vertical distribution of plankton should have been omitted are consequences of the subordinate part played by the physiological outlook and are to be regretted. However, there is no doubt that a more convenient repartition of the subject matter has been obtained by following taxonomic and phylogenetic principles in establishing communities. Physiological considerations would have imposed conflicts in some of these cases, and it is possibly better on the whole that the subject should be studied from special angles until we are able to make a logical synthesis. Whenever that time comes, it is certain that Professor Ekman's text-book will have rendered valuable service and will have laid a notable foundation.

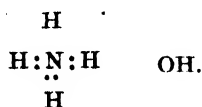
THE CHANGING FACE OF ORGANIC CHEMISTRY. By O. L. BRADY, D.Sc., F.I.C., University College, London. Being a Review of **The Organic Chemistry of Nitrogen**, by N. V. SIDGWICK, F.R.S. New edition, revised and rewritten by T. W. J. TAYLOR, M.A., and WILSON BAKER, M.A., D.Sc. [Pp. xx + 590.] (Oxford: at the Clarendon Press; London: Humphrey Milford, 1937. 25s. net.)

THE first edition of Sidgwick's *Organic Chemistry of Nitrogen* was published in 1910 and immediately became a standard reference and text-book. Unlike most such works its market value increased with the years since, after it had gone out of print, it was obtainable second-hand only at a high premium. That such a demand for the book remained twenty-five years after its publication is perhaps the best evidence of its excellence, for great advances had been made in its subject in the interim. The progress has been of two kinds, the first a vast accumulation of experimental results, important but less significant than the second, a complete change in outlook on the interpretation of the facts, due largely to the development of the electron theory. In 1910 nitrogen was considered to exhibit either trivalency or quinquevalency; in 1937 nitrogen is regarded as tricovalent or quadricovalent-unielectrovalent, and this change has profoundly modified our views of the structure and of the mechanism of reaction of nitrogen compounds. Perhaps this is

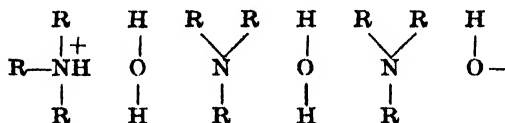
best indicated by the consideration of the basicity of amines. The quaternary ammonium hydroxides are strong, whilst ammonia and the amines are weak bases; this used to be explained by the notion that the former, in solution, were more electrolytically dissociated than the hydroxides of the latter, that is, that in the equations



the equilibrium lay much more to the right-hand side in (1) than in (2). Now undissociated R_4NOH cannot be represented electronically without violating the octet theory and a quaternary ammonium hydroxide and ammonium hydroxide must be completely ionised



The equilibria (1) and (2) cannot, therefore, exist and some other explanation must be sought for the feebly basic character of ammonia and the amines. It is possible to represent the equilibrium as $R_3N + H_2O \rightleftharpoons [R_3NH]^+ + OH^-$, but this leaves unexplained the solubility of the amines in water and the difficulty in extracting them from aqueous solution by means of organic solvents. Here the theory of resonance can be invoked. As a tricovalent nitrogen atom has a lone pair of electrons, which can acquire a proton just as the oxygen in water, the amine can form a link in the water "zwitterion"



The water molecule at the end of the chain loses a proton which forms an ammonium ion with the amine, which loses a proton to the next water molecule to give an oxonium ion. This exchange of protons between amine and water continues to the beginning of the chain when an ammonium ion remains. The reverse change can also take place and the resonance set up stabilises the chain. It must be stated that this view differs from the explanation given in the book, but seems preferable to the reviewer.

Again in the field of the stereochemistry of nitrogen the viewpoint has changed largely through the brilliant researches of Mills and his co-workers. The old view, that the space grouping about nitrogen was that the nitrogen atom occupied the apex of a pyramid with four valencies directed towards a quadrilateral base and the

fifth vertical, has been abandoned in favour of a tetrahedral arrangement of the co-valently attached groups about the nitrogen atom, the electrovalency having no direction in space.

These changes in outlook and the large amount of new experimental work have necessitated the complete re-writing of the book. Owing to pressure of other work Professor Sidgwick has been unable to undertake this but has entrusted the task to Messrs. Taylor and Baker who have had the assistance of numerous collaborators and the advice of Professor Sidgwick himself. One can say at once that the arrangement has been very successful and that for excellence of presentation, wealth of information and readability the new edition fully maintains the high standard of the previous one. It follows generally the same lines, but for fairly obvious reasons the purines and simpler alkaloids have been omitted to make room for subjects of greater theoretical interest and even then the book has grown by 175 pages.

Perhaps the best method of indicating the nature of the work is to give some account of the way a few topics are treated. The aliphatic and aromatic amines now occupy nearly double the space devoted to them in the first edition. All the more important methods of preparation are indicated, but the commercial manufacture of aniline from chlorobenzene now employed in the United States is not described. The chemical and physical properties are given and stereochemical problems discussed. The failure to isolate optical isomerides of trivalent nitrogen is explained on the generally accepted view that the nitrogen is at the apex of a very squat pyramid, and for this reason the molecule can easily turn inside out with consequent racemisation. It is pointed out that the sulphonium salts $[SABC]^+X^-$ and sulphoxides $abS \rightarrow O$ might be expected to behave similarly, yet they have been resolved and exhibit considerable optical stability. It seems to the reviewer that an explanation of the difference may be provided by the activity of the nitrogen lone pair of electrons. This lone pair may not unreasonably be presumed to be positioned on the side of the nitrogen atom remote from the three attached groups; if, now, one of these can become associated with one of the lone pair of electrons the extra pull will facilitate the turning-inside-out process; in the extreme the original lone pair may form the bond between the group and the nitrogen atom. In the sulphonium ion and the sulphoxides whilst the sulphur also has a lone pair of electrons these are very much less active, as evidenced by the failure to add a proton to form salts of the type $[abcHS]^{++}X_2^{--}$. Another point of interest in this section is the elucidation of the vexed question

of the structure of the triphenylmethane dyes by a simple application of resonance in the positive ion of the dye. The chapter devoted to hydroxylamine derivatives is notable for the first clear account of the chemistry and stereoisomerism of the oximes that has appeared in a text-book.

The section dealing with aromatic nitro-compounds is somewhat disappointing ; no mention is made of Masson's work on nitration nor of the preparation of nitro-compounds through nitroso derivatives from amines by oxidation with monopersulphuric acid followed by nitric acid, and the method given for the replacement of the diazonium group by the nitro group is quite antiquated. The authors cannot claim well-educated chemical noses if they believe that the odour of nitrobenzene is scarcely to be distinguished from that of benzaldehyde. The chapters on the diazo compounds are full of interesting material and the current views on the structure of, for example, diazomethane and the aromatic diazonium compounds are described with commendable clarity. One could deal with chapter after chapter and find points of note in practically every one ; the book is a mine of information, scholarly, eminently readable and except in a few minor details it is difficult to see how it could be bettered within reasonable compass. Some errors have escaped the proof-reading, but they are few in number and easily detected.

REVIEWS

MATHEMATICS

Mathematical Snack Bar. By NORMAN ALLISTON. [Pp. viii + 155.]
(Cambridge: W. Heffer & Sons, Ltd., 1936. 7s. 6d. net.)

THERE are many people, not necessarily mathematical schoolmasters, who find pleasure in reading about or inventing new mathematical theorems. Until we read the preface we were rather puzzled by the title of the book. How did the "bar" come in? The author has for many years collected a certain amount of original material. The essence of this he would gladly publish, but it did not run to one end and produce a connected treatise. But he saw it would produce a fund of lesser results, inventions, terms, considerations in geometry, arithmetic and allied subjects. This, although a handicap, need not be a bar; at least, not a bar to a snack bar. Hence the title to the book.

The author throws much light on old-world problems and states concisely and well new theorems and theorems of perennial freshness. He "features" an abbreviated method for developing the series of values that make biquadratic expressions square. This will be a help to the followers and exploiters of diophantine problems. He also caters for those who follow Fermat, whom he familiarly alludes to as "Fermatics" who try, for example, to find the factors of $10^{32} + 1$ and $10^{64} + 1$. The smallest of the factors of the smaller number is 19841. The finding of triangles with rational sides and areas is discussed. A shining light in this class is the triangle whose sides are 9, 10 and 17, its area equals the area of a square whose side is 6. Many of the problems given in geometry and trigonometry are original and would be excellent for training boys reading for mathematical scholarships.

His chapter on "proofs" is very good. He begins it by saying that the more obvious a fact is, the more difficult it is to prove. "About one-quarter of Euclid is an exhibition in the art of proving what we already seem to know; and that master in employing his craft was often put to extraordinary shifts. Witness more especially his *ad absurdum* proofs."

The writer knows that there are many people of mature years who find pleasure and relaxation in improving or inventing mathematical theorems. To these and to all boys and girls with a bent towards mathematics, he can warmly recommend this book.

A. RUSSELL.

PHYSICS

Elements of Nuclear Physics. By F. RASETTI. [Pp. xiv + 327, with 73 figures, including 8 plates.] (London and Glasgow: Blackie & Son, Ltd., 1937. 18s. 6d. net.)

THIS attractively printed volume comes with two immediate recommendations. It has for its subject a very recent and interesting branch of physics,

of which very few connected accounts have as yet appeared; and its author is himself a worker in, and an authority on, the subject. Prof. Rasetti has a terse and interesting style, and is able to convey to his readers an intelligible outline of any subject in a minimum number of words. He is thus able adequately to cover such topics as the General Theory of Radioactivity, the Interactions of Radiations with Matter, the Spectra of the Natural Radioelements, the Artificial Disintegration of Nuclei, and the Theory of Nuclear Structure, and still find room, at the end, for a chapter on Cosmic Rays. The book is well illustrated with line drawings in the text, and eight plates. A considerable number of Tables of collected experimental data adds considerably to the value of the work.

Prof. Rasetti's book is an admirable introduction to the experimental and observational part of the subject. A reader with only a general knowledge of physics should have no difficulty in following the greater part of it. In attempting to give some idea of the theoretical background of the subject, Prof. Rasetti for the most part avoids mathematical analysis, and contents himself, very wisely, with describing the underlying postulates and ideas. His treatment of these is as lucid as it can be made without becoming unscientific. Occasionally, however, the author has allowed himself to be led on to give fuller mathematical treatments of some parts of the subject. These require, on the part of the reader, at any rate some previous acquaintance with the mathematics of quantum mechanics, and are, perhaps, a little out of keeping with the standard of the rest of the text. However, the space which they occupy is comparatively small; they can easily be "skipped," and should not deter the less mathematically minded reader from a volume which, as a whole, provides an excellent survey of an interesting and important subject.

J. A. C.

Statistical Mechanics: The Theory of the Properties of Matter in Equilibrium. By R. H. FOWLER, M.A. Second edition. [Pp. x + 864, with 101 figures.] (Cambridge: at the University Press, 1936. 50s. net.)

THE appearance of a second edition of this book is very welcome. It is a mine of information on all subjects to which statistical mechanics can be applied. In branches of theoretical physics where progress has been rapid in the last few years the treatment has been brought thoroughly up to date. There is, for instance, a long chapter on the conduction of electricity in solids, with a full account of the properties of semi-conductors and of the author's own work on thermionic emission. In the section on ferromagnetism there is a lucid account of the permeabilities of single crystals of iron and nickel and their dependence on direction. There is a new chapter on "co-operative phenomena," such as order-disorder changes in metallic alloys and specific heat kinks in solids containing rotating molecules which can interact with one another. The chapter on interatomic forces has been revised and includes the most recent results. The same is true also of the chapter on stellar interiors, in which now the new fundamental particles discovered during the last few years may exist in equilibrium with more familiar forms of matter. In an appendix there is a very interesting description of Eyring's recent work on liquids.

As in the earlier edition the "method of steepest descents" is used to sum the series of the type which always occurs in statistical mechanics.

This elegant mathematical device, which was introduced into the subject by Darwin and Fowler, avoids, in the author's words, the "apparatus of factorials approximated to by Stirling's formula which disfigure the usual proofs." The method is based on the theory of integration in the complex plane; it would, however, be a thousand pities if physicists whose mathematical equipment does not reach as far as this should be deterred from consulting this book. Owing to its thoroughness and comprehensiveness, it will be for many years an invaluable work of reference; and in the chapters dealing with the application of the theory there should usually be no great difficulty in following the general gist of the argument, even with quite an elementary knowledge of the ideas of statistical mechanics. Especially valuable are the very detailed comparisons between theory and experiment.

The parts of the book dealing with the fundamentals of the theory have been very largely re-written; the earlier edition was published very soon after the invention of the new quantum theory, and the profound influence which these developments would have on statistical mechanics were not at that time entirely clear. The new edition incorporates the proved axioms of wave mechanics into the framework of the theory at an early stage, and, in view of the relative stability that atomic theory seems now to have attained, should prove a standard work of reference for many years.

N. F. MOTT.

The Theory of Metals. By A. H. WILSON, M.A. [Pp. viii + 272, with 31 figures.] (Cambridge: at the University Press, 1936. 18s. net.)

THE book is based on an essay which was awarded the Adams Prize in the University of Cambridge in the session 1931-32. Great advances have been made during the last ten years in the electron theory of metals and the time is opportune for a critical survey of the whole field. In addition to doing this the author gives a very complete theoretical account of the electronic properties of solids and pays particular attention to the assumptions involved and to the difficulties that still remain. Quantitative discussions of particular models except those of free or nearly free electrons were not undertaken because, as the author points out, it would be easy to induce a spurious idea of the success of the theory by a suitable manipulation of arbitrary constants. It will be necessary to obtain much more numerical data before satisfaction can be attained with the quantitative side of the subject.

The book contains six chapters. In the first chapter the electron theories of Drude, Lorentz, Bohr and Sommerfeld are discussed and it is indicated in which directions some of these theories may be improved. By eliminating the more difficult phenomena which depend on the mean free path, and considering only the properties of an ideal metal, a theory is set up which supplies sufficient information to enable many of the equilibrium properties of metals to be understood. The second chapter deals with the general theory of the motion of electrons in a perfect lattice. These two chapters are thus devoted to the development of the underlying ideas of the theory. In the remainder of the book these are applied to various problems concerning the equilibrium properties of metals such as the number of free electrons in metals, alloys and semi-conductors, the optical properties and the conduction of metals. A chapter is devoted to the mechanism which produces resistance in a metal and another chapter to the problem of superconductivity.

There are two appendices, one dealing with the Fermi-Dirac statistics and the other dealing with surface phenomena such as thermionic emission and rectification by crystal contacts.

The first two chapters of the book stand together, but the other chapters may be read independently and the non-specialist will find that some of these chapters give sufficient account of the applications of the theory. A detailed index is supplied.

The book is a valuable contribution to the subject and will repay careful reading. The physicist who wishes to keep abreast of modern developments can ill afford to be without it as the theory propounded is applicable to so many phenomena with which physicists are familiar in the laboratory. It can be heartily recommended not only because it contains a critical survey of electron theories, but also because it takes these theories a stage further, and if read carefully will supply information as to the lines of research which it would be fruitful to follow.

E. A. O.

Mechanics, Molecular Physics, Heat and Sound. By R. A. MILLIKAN, D. ROLLER and E. C. WATSON. [Pp. xiv + 498, with frontispiece, 54 plates and 268 figures.] (Boston: Ginn & Co., 1937. \$4.00.)

THIS text-book is described as "for the serious student who seeks a thorough training in science and engineering, who has already mastered trigonometry, and who has had the equivalent of a good secondary-school course in physics." The authors have gone far beyond their original plan, which was simply to revise the senior author's *Mechanics, Molecular Physics and Heat*.

The book deals with much of the work required in a "pass" or "general honours" degree course, and the treatment is very thorough. About thirty laboratory experiments are described; and there are optional laboratory problems, together with many questions and problems, some of which are solved in full or in outline. Of the fifteen chapters, eight deal with mechanics and elasticity; two are concerned with the kinetic theory of gases and the properties of vapours; and two are devoted to periodic motion and sound.

A very noticeable feature of the book is the inclusion of "some of the historical and humanistic backgrounds of the subject." There are lists of some of the important original papers in physics; lists of biographies of noted physicists; lists of books on the history, methodology and philosophy of physical science. And throughout the text reference is made to the original workers in the different parts of the subject.

All this historical detail is included without affecting the thoroughness of the book as a text-book. On the other hand, there are 54 plates dealing with the history of physics, and although these plates, together with the corresponding descriptions, are admirable in themselves, they are inserted in such a way as to cause rather disconcerting interruptions in the text of the book.

W. N. BOND.

Disperse Systems in Gases: Dust, Smoke and Fog. A general Discussion held by the Faraday Society, April 1936. [Pp. 258, with 4 plates and numerous figures.] (London: Gurney & Jackson, for the Society, 1936. 12s. 6d. net.)

THE discussion held in April 1936 at Leeds, under the auspices of the Faraday Society, to deal with disperse systems in gases, provides yet another instance

of the valuable work which that body undertakes in bringing together investigators from many lands for a definite and limited purpose. Sometimes the main theme has been academic, sometimes industrial. The report now before us represents a very welcome blend of these two influences.

Dust, smoke and fog provide problems enough for the University Laboratory; they envelop, both literally and metaphorically, a host of new issues. Part 1 (a) comprises a group of papers dealing with smoke, dust and oil fogs, while Part 1 (b) is concerned with mist, cloud and hygroscopic nuclei. Part 2 is devoted to industrial questions.

Dr. J. S. Owens gives a most interesting account of the progress made in smoke abatement during the past twenty-five years. In some respects the advances made seem to be trivial, yet they represent a great deal of effort when one recollects the increase in population in many cases. London has remained almost stationary, with a slight tendency to improvement. A paper by Firkot gives details of the exceptionally devastating fog which covered a large part of Belgium a few years ago and which led to considerable loss of life. For this disaster an unusual concentration of sulphur seems to have been responsible. An elegant use of dimensional analysis permits Bosanquet and Pearson to arrive at valuable conclusions concerning the height of chimneys and the position of maximum deposit of matter at ground level.

Altogether this meeting and the exhibition which accompanied it may be said to have given fresh impetus to the study of disperse systems and atmospheric pollution.

F. I. G. RAWLINS.

The Climates of the Continents. By W. G. KENDREW, M.A. Third edition. [Pp. xii + 473, with 160 figures.] (Oxford: at the Clarendon Press; London: Humphrey Milford, 1937. 21s. net.)

THE author of this book states that he aimed at providing "an adequate description of the actual climates of the countries of the earth, considered regionally." We can, without any reservations, say that he has achieved this aim in a remarkable degree, and has not only put into a clear form all the relevant facts, but has also clothed these facts with a considerable amount of human interest. The book begins with a brief discussion of the nature of climatic statistics, followed by an account of the relation of the winds to the distribution of pressure. The continents are then considered in turn, each being divided into convenient sub-divisions, a chapter being devoted to each sub-division. Each chapter gives the general features of the climate, illustrated by very clear maps, while at the end of the part devoted to each continent are given tables of monthly and annual mean temperatures, and monthly and annual mean rainfall totals. These tables in themselves form a very useful collection of information, and the reader who desires to find out the general nature of the climate of any particular place cannot do better than consult this book. The present reviewer has used Kendrew's *Climates of the Continents* for this purpose for many years, and has always found it adequate. He has also found it suitable for systematic study by students of Meteorology. It is of course necessary to bear in mind that mere statistics cannot tell all the facts, unless the statistics are so voluminous that no one volume can deal with the whole earth. There are regions of the earth where no rain falls during ten or even twenty consecutive years, and then a single thunderstorm may give one or two inches of rain in a single day. The meaning of a figure for the

mean annual rainfall of such a place is by no means obvious. Where it is readily possible Kendrew gives in the text the guidance which the reader requires if he is to avoid being misled by the bare statistics.

Not least of the advantages of the book under review is that it gives for the whole earth data in a uniform system of units, and the reader is spared the exasperation of having data in different units for different countries. It is a book which the student of Geography or Meteorology will find invaluable.

D. B.

Vibration and Sound. By P. M. MORSE. International Series in Physics. [Pp. xv + 351, with 3 plates and 88 figures.] (New York and London: McGraw-Hill Publishing Co., Ltd., 1936. 24s. net.)

RECENT years have witnessed great advances in all branches of Physics, and although for the Science of Acoustics they may be less spectacular than for, say, Atomic Physics, nevertheless in compensation they possess a greater measure of reality.

Experimental advances have already received attention from various authors and the present volume is designed to fill a gap by giving a modern presentation of the theoretical aspects of the subject. As an example of the application of modern methods to problems associated with sound, it may be mentioned that in the last chapter of this book concerned with the acoustical properties of rooms the author applies the mathematical technique developed to meet the needs of the quantum theory, in particular in this case, for the study of the radiation of light from an atom.

As suggested by the title, the author has given a thorough consideration to the fundamental theory of the vibrations of solid bodies and of the propagation of sound waves, leading finally in the last two chapters to radiation and scattering and to standing waves of sound. Quite a useful feature is the large number of problems illustrative of the practical application of the subject matter, with which each chapter concludes.

The volume should prove very useful to students of mathematical physics and to others prepared to face mathematical problems. To research workers and others engaged on acoustical problems, it will be a necessity as a work of reference. Readers will at once realise that the book is a valuable addition to acoustical literature, being in many respects complementary to existing text-books.

The advent of a second addition will provide an opportunity of modifying the few pages devoted to the Vibrations of a Whirling String, to the necessity of which attention has been drawn.¹

Nothing more need be said than that the production is well up to the standard which we have been led to expect for additions to the International Series.

R. E. G.

Physical and Chemical Constants. By G. W. C. KAYE, O.B.E., M.A., D.Sc., F.Inst.P., and T. H. LABY, M.A., Sc.D., F.R.S. Eighth edition. [Pp. viii + 162.] (London, New York, Toronto: Longmans, Green & Co., 1936. 14s. net.)

In its eighth edition this indispensable book has undergone considerable revision, although there has been no increase in its size. Many of the con-

¹ A. C. Stevenson, "A Note on the Vibrations of a Rotating Rope," *Phil. Mag.*, 24, 292, 1937.

stants for pure metals given in the booklet prepared at the National Physical Laboratory last year have been included and the sections on thermometry, magnetism and X-ray spectra have received special attention. There are data for heavy water, Kellströms value for the viscosity of air is included, there is a considerable list of isotopes and the bel and phon are defined. On the other hand, there seems to be no mention of superconductivity or of the results of the experiments on steam carried out at the Bureau of Standards. The section on p. 47 devoted to thermodynamic corrections to gas scales of temperature contains no reference later than 1909 and the sentence "New experiments on the Joule-Thomson effect are needed" still appears, although in the preceding table recent values for the thermodynamic temperature of the ice-point (obtained by extrapolation to zero pressure) are quoted. There will be ample opportunity to amend this section in two or three years' time if the authors consider it desirable.

D. O. W.

The Physics of Electron Tubes. By L. R. KOLLER, Ph.D. Second edition. International Series in Physics. [Pp. xvii + 234, with 84 figures.] (New York and London: McGraw-Hill Publishing Co., Ltd., 1937. 18s. net.)

IN this second edition Dr. Koller has retained the same scope and treatment as in the first, published in 1934: a non-mathematical exposition of the physical principles underlying the operation of various electron tubes. External circuits are not considered. Nearly thirty pages of new material have been added, including sections on electron optics, cathode ray oscillographs, secondary electron multipliers and positive ion emission. There has been some rearrangement, while the very useful bibliographies at the end of each chapter have been brought up to date.

In some cases the addition of new material without modification of the old may cause confusion. For example, in Section 8 a paragraph on Schottky field currents (proportional to the square of absolute temperature) is now followed by "an expression for field current or cold cathode emission, as it is sometimes called" (independent of temperature), without drawing sufficient distinction between the two cases. In future editions revision of these sections would not only avoid such confusion but eliminate some existing repetitions. It is disconcerting to find the thermionic constants for oxygenated tungsten still given as $A = 5 \times 10^{11}$ and $\phi = 9.2$ instead of < 120 and 6.3 respectively, and ϕ for platinum as 6.27 instead of 5.3 .

On the whole, the book remains a reasonably clear and accurate account of the physics of electron tubes, but more elementary and less detailed than its inclusion in the International Series in Physics would lead one to expect.

F. A. V.

Electron Tubes in Industry. By KEITH HENNEY. Second edition. [Pp. viii + 539, with 397 figures.] (New York and London: McGraw-Hill Publishing Co., Ltd., 1937. 30s. net.)

As one turns over the pages of electrical and instrument journals it seems that every other paper is concerned with application of electron tubes, new or old. Since 1934 the seeker of a circuit for a particular purpose has turned with relief to the collection in the book by the editor of *Electronics*. He will now use the second edition, which has been entirely reset and includes fresh material, adding some 40 pages to a volume already large. The least successful parts of the book are still those dealing with fundamentals of electron tubes and

associated circuits, but the author's main purpose is to set out the applications of electronic devices to industrial problems, excluding communication (radio, television, etc.). Under the general headings of Vacuum-tube Amplifiers, Gaseous Triodes, Light-Sensitive Tubes and Miscellaneous Tubes a large number of circuits have been gathered together. One feels that a rather stronger critical sense might have been employed with advantage in the choice and description of circuits, and that much of the elementary introduction in the first two chapters could have been omitted or shortened.

The experimenter will not find here a workshop manual or constructor's guide, but numerous references to original papers and general articles are given. The tubes and circuits described are almost entirely American in origin, in fact, a newcomer to the subject would judge from this evidence that the use of electron tubes in other countries is quite negligible! This does not mean that the book will not interest a British reader, though he may have to redraw some of the circuit diagrams before being able to read them easily.

Very few will read every page of this volume, but it will certainly be taken down frequently from the selected reference books on the laboratory shelf.

F. A. V.

An Introduction to Neon Lighting. By J. ORR, M.I.E.S., and A. W. FORREST, B.Sc. Blackie's "Technique" Series. [Pp. viii + 79, with 37 figures.] (London and Glasgow: Blackie & Son, Ltd., 1936. 3s. 6d. net.)

THE use of gaseous discharge tubes, particularly for advertising and display purposes, has now become established as an important branch of artificial lighting technique, and an authoritative book dealing with the technical aspects of the subject has been for some time overdue.

The author gives an excellent account of the manufacture of neon tubes, details of the associated equipment, erection and maintenance. This account is not restricted by any apparent desire to withhold information about special manufacturing processes guarded by the trade, in fact, a full and frank discussion of the various problems involved is the essence of the author's success.

As indicated by the title the book is practically entirely confined to neon discharge-tubes. In view of the recent extensive development of other types of discharge tube, particularly for use in conjunction with neon, for example the combination of mercury vapour and neon to give white light, one feels that the scope of the book might with advantage be extended to cover commercial gas discharge-tubes generally.

For those electrical engineers and contractors who wish to enter the field of neon lighting the book should prove a valuable introduction and is well worth careful study. As the author says, neon lighting is really a specialist's job. There are many pitfalls, some of which can only be avoided by experience, but as the art of neon lighting develops, electrical contractors will certainly be called upon to have a good working knowledge of the equipment, and this book can be recommended as an excellent means to that end.

H. M. BARLOW.

Commercial A.C. Measurements. By G. W. STUBBINGS, B.Sc., F.Inst.P., A.M.I.E.E. Second edition. [Pp. xvi + 348, with 169 figures.] (London: Chapman & Hall, Ltd., 1937. 15s. net.)

THE first edition of this book was published in 1930, and electrical engineers concerned with power frequency metering systems, particularly those engaged

in testing work, have frequently had reason to be grateful to the author for helping to elucidate their problems. In the second edition some valuable new matter has been incorporated, dealing mainly with the principles and applications of the method of symmetrical components for the resolution of unsymmetrical three-phase circuits. The sections devoted to current transformer testing, reactive and kVA meters have also been considerably extended and brought up to date.

The book makes no attempt to cater for those interested in high frequency measurements. This is rightly regarded as a separate field, but the development of the telecommunications industry has made that field no less important to-day. The title of the book, which does not indicate its restricted scope, is therefore somewhat misleading.

The author introduces his subject with a résumé of alternating current theory. His treatment of vector representation with special reference to the sense of the vectors as indicated by the arrowheads is well worth careful study, because it is in connection with this convention, which is usually only very superficially discussed, that misunderstanding so frequently arises. The chapters that follow are devoted in turn to the measurement of current, voltage and power, to instrument transformers, to the measurement of energy, power factor and frequency, to the determination of phase sequence, reactive volt-amperes, kilo-volt-amperes, and finally to test-room equipment. There is also an appendix which includes some notes on the trigonometry of A.C. theory. Each chapter deals adequately with what it sets out to do. The presentation is at once clear and concise without any undue emphasis or obvious omissions. The space allocated to instrument transformers is perhaps larger than some would consider to be justified, but most readers will welcome the thoroughness which characterises the author's work. The revision and enlargement of the book for issue as a second edition has considerably enhanced its value. Every electrical engineer will find within its pages much to learn. With the numerous helpful suggestions for overcoming metering difficulties and getting the best results under exacting conditions of operation, the book may well be regarded as indispensable by those engineers who are particularly concerned with power frequency measurements.

H. M. BARLOW.

Electrical Measurements: Precise Comparisons of Standards and Absolute Determinations of the Units. By HARVEY L. CURTIS, Ph.D. International Series in Physics. [Pp. xiv + 302, with 66 figures.] (New York and London: McGraw-Hill Publishing Co., Ltd., 1937. 24s. net.)

In view of the change in 1940 from international electrical units to absolute units, the various national laboratories are busy increasing the accuracy of absolute electrical measurements in order to reduce their differences to one or two parts in a hundred thousand. At such a moment the appearance of this volume of the International Series in Physics is particularly opportune, and the whole series is enriched by the able and lucid account given by Dr. Harvey Curtis of the Bureau of Standards, Washington, who for years was associated with the late Dr. E. B. Rosa.

This book centres around the absolute measurement of the ohm and ampere, but at least one precision method of comparing resistances, electro-

motive forces, inductances and capacitances is given as well as an account of the construction of standards and of the calculation of necessary inductances. Mention might have been made of modern mutual inductometers and, in section 71 on the comparison of inductances, of the Heaviside-Campbell equal ratio bridge.

The author outlines briefly the underlying principles of many of the methods of measuring resistance and current absolutely, and then wisely singles out precision methods for detailed description. Thus, in the case of resistance, he concentrates on the Smith-Lorenz method (suggesting a modification for future work) and on the self-inductance method with an intermediary capacitance. This latter method, first put into use at the Reichsanstalt in 1920 by Grunewald and Giebe, has been carried out as recently as 1936 at the Bureau of Standards by Curtis, Moon and Sparks, and is of great importance. Likewise three precision methods for the absolute measurement of current are described in detail, namely, those involving the features of the Rayleigh current balance, the Ayrton-Jones current balance and the electro-dynamometer balance.

The value of the book is greatly enhanced by the remarkable simplicity and clearness of the diagrams dealing with elaborate apparatus. Fig. 50, showing the "setup for the absolute measurement of resistance, using alternating current in a self inductance combined with an intermediary capacitance," is particularly attractive.

H. R. NETTLETON.

The Electrical Handicraftsman and Experimenter's Manual.

By H. R. LANGMAN and J. H. MOORE. [Pp. viii + 192, with 187 figures.] (London: The Technical Press, Ltd., 1936. 7s. 6d. net.)

THIS book is intended for the home experimenter. It contains a large number of diagrams and descriptions of "gadgets" to delight the heart of the enthusiastic model maker. Perhaps the best chapter from this point of view is that dealing with small electromagnetic devices. Unfortunately, the authors have strayed into fields obviously less familiar to them and have introduced several strange-looking valve circuits and models illustrating the "mechanism of the electric spark," electrolysis, etc., which are not very illuminating. Also it is somewhat surprising in a practical book of this kind to find a few diagrams grossly out of scale. For example, in Fig. 133 we have an ordinary solenoid as long as a metre bridge.

Some of the electrical theory introduced is decidedly unorthodox. Describing the production of an electrodeless discharge in a gas-filled electric lamp, the authors state that "with some bulbs it is possible to hear the electrons bombarding the glass, which at this stage is vibrating and emitting a ray of purple light . . ." (p. 146). For electromagnets "to yield best results the core should be laminated, the idea being to present a larger surface area to the flow of magnetism" (p. 57), though on a later page the use of insulation between laminations to reduce eddy-current loss is correctly described.

We therefore cannot recommend this book as a whole to those just taking up the study or hobby of electricity, but with some knowledge to guide him an enthusiast will be able to pick out several ingenious devices scattered among the many descriptions.

F. A. V.

B B

Elements of Practical Aerodynamics. By BRADLEY JONES, M.S.
[Pp. vi + 398, with 123 figures.] (New York : John Wiley & Sons,
Inc. ; London : Chapman & Hall, Ltd., 1936. 18s. 6d. net.)

THAT simplest part of the applied science of Aerodynamics, *viz.* the principles of flight, is easy to follow. With little demand on mental equipment, treatment may even be elaborated to indicate the directions in which scientific and technical study lie. Add introductory notes of a practical nature on aircraft types, construction and materials ; engines, cowlings and propellers ; instruments ; meteorology and aviation (as one says in America) ; and there will evidently result a readable subject for all who possess an engineering sense though not necessarily an interest in science.

Prof. Bradley Jones's book appears to be written largely from this point of view and to serve a useful purpose in a certain field. It conveys a good idea of what aeronautics is about, putting in practical detail and interesting asides. Orientation is mostly in the right direction, although in these days one would expect greater prominence to be given in a practical book to flaps, skin friction and supercharging. The chapter on monoplane theory assumes too much to be satisfactory, but applications, particularly to the biplane, are worked out at length. Most interest will centre in the chapters on performance calculations and on matters which are usually omitted from a course in Aerodynamics. Another title, more appropriate to the subject matter as a whole, might have been preferable. Where merely qualitative explanations are avoided the numerical treatment is detailed. It is not intended for practising engineers and is no more suitable for University students. Most English readers will feel an inconvenience in doing so largely without the calculus.

N. A. V. P.

Practical Physics for Inter. B.Sc. Students. By H. M. BROWNING, M.Sc., Ph.D., F.Inst.P., and L. STARBUCK, B.Sc., A.Inst.P. [Pp. x + 146, with 46 figures.] (London : Blackie & Son, Ltd., 1936. 3s. 6d. net.)

THIS little book contains descriptions of over eighty experiments. The space devoted to each is rather short, and the authors' claim that " the practical details of the experiments are described " is not always justified. For instance in the comparison of low resistances (lengths of stout wire) no mention is made of potential leads, and in the same experiment the galvanometer which is used as a voltmeter may, apparently, be of any resistance and type. In fact, it might be ballistic—unless by " quantity of electricity " the authors mean " current."

However, the book will fit easily into the pockets of those candidates who wish to refresh their memories on the way to the practical examination. Each section is followed by a number of exercises in which the straight-line graph frequently appears, and the candidate who has penetrated its various disguises will be prepared for the worst that may befall.

R. C. B.

CHEMISTRY

Intermediate Chemistry. By T. M. Lowry, C.B.E., M.A., D.Sc., F.R.S., and A. C. CAVELL, B.A., B.Sc. [Pp. xvi + 876, with 188 figures.] (London : Macmillan & Co., Ltd., 1936. 12s. 6d.)

IN the preface the authors state that their object is to provide a complete textbook of chemistry for the Intermediate and Higher School Certificate Examina-

tions. This book therefore includes under one cover sections on General and Theoretical, Inorganic and Organic, Analytical and Physical Chemistry. It is an ambitious project, for to maintain a uniform standard of excellence throughout these diverse sections is no easy achievement. Nevertheless, in the opinion of the reviewer this has been accomplished. This success is in part due to the fact that in preparing this volume the well-known text-books written by the senior author, alone or in collaboration, have been drawn upon. The inorganic section, though founded on Lowry's *Inorganic Chemistry*, has been completely reconstructed, but the sections on physical chemistry closely resemble those portions of Lowry and Sugden's *Class Book of Physical Chemistry* which have been used. However, the four chapters on inorganic analysis and the whole of the section on principles of organic chemistry are new. The authors have emphasised throughout their book the theoretical implications of the facts they record. For example, in the organic section Lapworth's interpretation of the cyanhydrin reaction is quoted and Robinson's explanation of the contrast between the unsaturation of the olefines and of ketones. From this it will be realised that there is a fuller discussion of underlying theories than is customary even in some advanced text-books of organic chemistry. In the reviewer's opinion this is all to the good, especially as some idea of the structure of matter and the electronic theory of valency are given nowadays in the elementary courses. An important feature of the volume is the series of 190 experiments which have been tested in school classes and found to be of great value as a training in practical chemistry. It should be mentioned, also, that typical questions have been collected and classified so that the student may test his progress. The broad and accurate scholarship of the writers is reflected throughout the book and the book should commend itself to a wide circle. There must, however, linger in the minds of teachers of chemistry, who peruse the pages of this book, the very real question whether it is usual or even desirable for young students preparing for Intermediate and Higher School Certificate Examinations to reach this standard of chemical knowledge.

W. WARDLAW.

Inorganic Preparations. By A. KING, M.Sc., A.R.C.S., D.I.C. [Pp. xii + 164, with 22 figures.] (London : Thomas Murby & Co. ; New York : D. van Nostrand Company, 1936. 5s. 6d. net.)

In the preface the author states that "this book is a plea for the wider use of inorganic preparations in the teaching of inorganic chemistry." It is, unfortunately, still true that the course in practical inorganic chemistry is, in many places, restricted to qualitative and quantitative analysis. Thereby the student is denied the opportunity of investigating for himself some of the fascinating chemical reactions which abound in inorganic chemistry. It is a most curious fact that whereas in organic chemistry preparations are considered a vital part of the course, preparative work in inorganic chemistry is frequently considered either to be quite unnecessary or of very secondary importance. Inorganic preparations, as the author points out, do require more elaborate apparatus than analytical chemistry. They also necessitate a greater expenditure on materials and demand constant supervision. Nevertheless, it cannot be denied that the student finds them of the greatest interest and they do provide an excellent training in technique and illustrate a wide range of chemical principles. There is no doubt, therefore, that the author is

rendering a real service to teachers of inorganic chemistry in bringing together within the compass of a book of very modest price a varied selection of valuable inorganic preparations. In addition to 187 preparations, given in full, an approximately equal number of preparations are outlined. The preparations are classified under seven headings, illustrating (1) physical state, such as allotropy and the colloidal state, (2) isolation of the elements, (3) binary compounds such as hydrides, polyhalides, nitrides, etc., (4) acids, bases and salts, (5) complex salts, (6) compounds of some rarer elements, (7) reactions which form the basis of some industrial processes. The book can be most warmly recommended and should have a wide use in both schools and universities.

W. WARDLAW.

Lecture Experiments in Chemistry. By G. FOWLES, M.Sc., A.I.C., F.C.S. [Pp. xvi + 564, with 150 figures.] (London: G. Bell & Sons, Ltd., 1937. 16s. net.)

To lecture and at the same time to perform a number of experiments before a class of students is one of the most difficult tasks in the teaching of chemistry. If the experiment is a success, then some fundamental law may be transformed in the mind of the student from an abstract principle to a concrete fact, but if the experiment is a failure then doubts are raised and the prestige of the teacher suffers. Few teachers have the time to work out for themselves the details and technique of the many experiments which are necessary for even an elementary course of lectures, and in the past they have depended upon the works of Henmann, Benedict and the familiar Newth for help, but more than thirty years have passed since the last edition of these books appeared. During this time chemistry has developed and methods of teaching have been revolutionised. The time was therefore fully ripe for a new presentation of this branch of experimental chemistry. Mr. Fowles has undertaken the task and done it magnificently. Moreover, he has not light-heartedly sat down to write a book. The contents represent the experience of a lifetime of teaching and the writing has been the labour of years.

The 547 experiments range from those suitable for the youngest pupil to students taking the Intermediate Science Examination and the author has always borne in mind that experiments are intended to instruct and not to entertain, and that simple apparatus ingeniously used adds to rather than detracts from the value of a demonstration. The book is thus designed more for use in schools than in universities, but it contains so much sound advice, shrewd comment and common sense that it may be used with profit by all responsible for an undergraduate course in inorganic chemistry.

The appendix is specially interesting. In 43 pages the author discusses the aims and methods of teaching chemistry and reviews the relative merits of the systems which have been tried out in the past. He quotes the opinions of such diverse people as Plutarch, Armstrong, Smithells, Karl Pearson and Ida Freund and has included an appreciation of the teaching methods of those giants of the past, Davy, Huxley, Dewar, Ramsay, Perkin and Fenton.

The book is handsomely produced, contains 150 very clear diagrams and abundant references to the literature. It is very free from slips (amyl acetate, p. 349, should read amyl alcohol) and ought to be possessed and used by all engaged in teaching chemistry.

J. N. S.

Modern Elementary Chemistry. By F. SHERWOOD TAYLOR, Ph.D., M.A., B.Sc. [Pp. xii + 461, with 8 plates and 118 figures.] (London : William Heinemann, Ltd., 1936. 5s.)

Handbook to Modern Elementary Chemistry. By F. SHERWOOD TAYLOR, Ph.D., M.A., B.Sc. [Pp. vi + 137, with 3 figures.] (London : William Heinemann, Ltd., 1936. 6s. net.)

THE plan of producing a teacher's handbook to supplement the text-book is admirable and the reviewer hopes that the practice will grow. So many extra duties fall upon teachers to-day that few can find time or energy to keep up-to-date in their subject as they would wish. It is precisely for that reason that these two new books by Dr. Sherwood Taylor are so valuable. He has set himself to offer within one volume an adequate amount of information for the training of students up to School Certificate stage in Chemistry without, however, neglecting the wider interests that the study opens up and without, for the sake of simplicity or tradition, introducing ideas which will have to be unlearned at the next stage. This latter point is, in the reviewer's judgment, of the utmost importance and in this respect many otherwise excellent text-books fail. The work, throughout, shows a scholarly and well-informed chemist seeking to present his information clearly and without burking difficulties and as such it will appeal to every able student and good teacher. There is an adequate supply of questions at the end of every chapter, diagrams are generally clear and the plates well printed and interesting.

The Handbook contains details of experiments which are not explained in the text and many other interesting experiments which are less well known but well worthy of performance. In addition it gives much useful information for illustrating specific points, such as the difference between a hydron and a hydrogen atom.

With a good form the text-book should prove a most valuable teaching instrument. It is doubtful, however, whether the very virtues of the book might not prove a difficulty with a "B" form who find the subject rather a strain. Perhaps this is an argument against teaching chemistry, as chemistry, to such a group when elementary General Science might be more readily absorbed.

Dr. Sherwood Taylor hopes that his book will teach the student nothing that he will later have to unlearn. Unfortunately, however, the book is probably too difficult to put into the hands of an average third form who are commencing chemistry, and so by the time they reach Dr. Taylor's book they will probably have learned a number of things which his book will teach them to unlearn. But for that reason this book and the handbook ought to be thoroughly examined by all teachers of the subject in schools.

C. H. D.

Quantitative Analysis. By WILLIAM RIEMAN, Ph.D., and JACOB D. NEUSS, Ph.D. [Pp. ix + 425, with 45 figures.] (New York and London : McGraw-Hill Publishing Co., Ltd., 1937. 18s. net.)

MODERN text-books of Quantitative Analysis are tending more and more to become treatises on applied physical chemistry, and this book is presented by the authors as being a further step in this direction. The experiments are designed to cover two semesters. During the first semester simple volumetric and gravimetric exercises and potentiometric measurements are performed, the order of the experiments in the book being strictly followed.

The second semester is devoted to more difficult exercises and some liberty of choice is permitted. Each experiment is discussed clearly and with great theoretical detail. Special emphasis is laid on errors due to co-precipitation in gravimetric analysis, and end-point errors due to the indicator used in volumetric analysis. The appendix contains useful tables of density, ionisation constants, solubility products, normal electrode potentials and a comprehensive bibliography of text-books on analysis and related subjects.

It is not always easy to hold the balance between theory and practice in presenting a course of this kind. When, as in this book, the theoretical aspect is specially emphasised, the difficulty arises that it demands a knowledge of physical chemistry often beyond the attainments of the beginner working through the course, and the student ought to be warned that even a profound knowledge of theoretical physical chemistry cannot replace long hours spent at the laboratory bench, if accuracy and confidence are to be gained.

Like others in the International Chemical Series, the book is excellently produced and free from errors and contains all that is necessary for a complete understanding of the principles of quantitative analysis.

J. N. S.

Elements of Chemical Engineering. By WALTER L. BADGER and WARREN L. McCABE. Second edition. Chemical Engineering Series. [Pp. xvii + 660, with 311 figures.] (New York and London: McGraw-Hill Publishing Co., Ltd., 1936. 30s. net.)

THIS is the best book now available for an introductory course in chemical engineering. Under these circumstances it is justifiable to raise the standard of criticism in reviewing the second edition.

An essential factor in teaching students is to indicate to them how difficulties have arisen in the past and how human ingenuity has overcome them. In this way they are prepared more efficiently for the time when they too, in their turn, have to solve the problems of their profession. The present edition savours too much of the addition of a few recent researches and not sufficiently of a thorough overhaul to make sure that the foundations are adequate. There is always the disadvantage in the inclusion of the results of researches not more than two or three years old in that they have not stood the test of time and are, in general, unsatisfactory material for the embryo chemical engineer. This comment applies, for example, to the unnecessarily elaborate treatment accorded in this edition to extraction processes.

One distinct advantage of this edition is that dimensionally consistent units have been employed when considering fluid flow problems. It is a pity, however, that the authors did not revert completely to Stanton's original nomenclature but have retained the friction factor as f instead of defining it more in detail. There are still a number of loose statements. For example, the student is advised to subdivide caliche finely to hasten the extraction of nitrate. If he did so he would probably not extract any at all owing to the formation of a thick slime. The extraction of tan bark is said to take place rapidly and that from sugar beet slowly. Actually the times of extraction are from 24 to 8 hours for tannins and 45 minutes for sugar, and the sugar in the wood chips always comes out before the tannins.

M. B. DONALD,

Applied Chemistry for Engineers. By A. F. H. WARD, M.A., Ph.D., B.Sc., A.I.C. [Pp. xi + 127, with 6 figures.] (London, New York, Toronto : Longmans, Green & Co., 1936. 5s.)

To declare that a chemical engineer is an engineer in the company of chemists and a chemist in the presence of engineers is a facile jest ; but to interest an engineering student in the principles of chemistry or a chemistry student in the large-scale technique and economics of his preparations is often less facile. Perhaps this is because his vision is dimmed by his being in the shadow of an examination syllabus ; perhaps only because he lacks a guide to objects of interest in the common field. This small book is such a guide, but one which starts by assuming that those who desire to apply their knowledge of chemistry have already acquired that knowledge to an adequate degree. It assumes that the student possesses that competence which can be gained from a first-year chemistry course in a technical college or university ; and it assumes further that the student is in fact studying the subject in hand, not relying only on the author's experimental illustrations or expecting that this volume will turn him, at a cost of three hours a week for a year, into a chemical technologist. Dr. Ward has, however, made a distinct contribution to educational apparatus by collecting together a large number of suitable experiments, describing clearly how they may be performed, and indicating the fundamental considerations involved. The engineering student who supplements his practical work in general elementary chemistry and his theoretical studies in applied chemistry by using this book at his bench should find that his interest is stimulated and his understanding broadened. He will learn a good deal about the analysis of water supplies, the treatment of boiler water, the conditions conducive to metallic corrosion and its prevention, and the examination of coal and oils. And if he also gains an appreciation of the way in which modern industry depends on the combined and correlated work of both engineers and chemists he will be the better equipped for his career.

A. A. E.

Thorpe's Dictionary of Applied Chemistry : Supplement, Vol. III : Glossary and Index. By JOCKLYN FIELD THORPE, C.B.E., D.Sc., F.R.S., F.I.C., and M. A. WHITELEY, O.B.E., D.Sc., F.I.C. [Pp. viii + 166.] (London, New York, Toronto : Longmans, Green & Co., 1936. 21s. net.)

This volume completes the supplement to the third edition of Thorpe's *Dictionary*. One hundred pages are devoted to a glossary of words and phrases employed in the supplementary volumes the meaning of which is not obvious, in addition a number of other terms in constant use among chemists are defined. It is not easy to see what principles have determined the choice but the range is wide, the definitions or explanations clear and terse and, at a time when every new reaction is labelled with the name of its discoverer and the coining of words to associate with phenomena is rife, there is no doubt that the glossary will be very useful. An index to a dictionary is, perhaps, unusual but, in this case, it is a necessity, as the supplementary volumes were more a collection of articles and reviews on recent topics than a dictionary in the usual sense.

O. L. B.

Metallic Corrosion, Passivity and Protection. By ULICK R. EVANS, M.A., Sc.D. [Pp. xxiv + 720, with 93 figures.] (London: Edward Arnold & Co., 1937. 45s. net.)

THE appearance of this book will be heartily welcomed by all interested in the great corrosion problem and phenomena related thereto, whether it be an absorbing interest or an occasional or spasmodic interest only during the solving of some corrosion problem or the devising of some method of protection under a given set of conditions. A few hours given to this book in connection with any such problem will yield more value than days spent in an otherwise well-equipped library without it.

The author did well in deciding to write a new book instead of revising his previous well-known book on *Corrosion of Metals*, the second edition of which appeared in 1926, for during the intervening eleven years an enormous amount of work has been carried out by research workers all over the world. The references given to published matter cover the work of some 1700 authors, taken from about 300 periodicals actually listed, and in addition the author acknowledges permission to publish special information communicated by some eighty well-known investigators, so that the book will undoubtedly be in great demand as a reference work alone. Special attention is given to the work carried out by the author and his collaborators in Cambridge since 1923, and this greatly enhances the value of the book. It comprises fifteen chapters, the headings of which are such as would be expected in a book on these subjects, and the author has a novel method of sub-dividing these chapters into three sections devoted to: A, the scientific basis of each subject dealt with; B, the discussion of practical problems; and C, a quantitative discussion of certain cases which are sufficiently simple to be represented by equations and the grasping of the meaning of which requires a knowledge of mathematics, etc., which is not necessary for sections A and B. This certainly simplifies the use of the book for reference purposes, and has much in its favour.

There is one interesting exception to this division of chapters into three sections, for to Chapter 5, which deals with corrosion by stagnant liquids and includes matters connected with the investigation of differential aeration currents, corrosion and protection of buried pipes and corrosion velocity under certain conditions, there is added a fourth section containing an account of the views of Drs. Bengough and Wormwell as supplied by these workers. The supply of this material and its inclusion in the book by the author shows the spirit which should always be in evidence in the case of scientific controversy.

The formation and the nature of films on metallic surfaces receives considerable attention, and such questions as growth of cast iron and oxidation at high temperatures are dealt with. There are valuable chapters on the protection of metallic surfaces and also on the methods of testing.

The book is well written, well printed and illustrated, and will provide a standard book of reference for many years.

C. O. B.

Water Purification Control. By E. S. HOPKINS. Second edition. [Pp. x + 184, with 48 figures.] (London: Baillière, Tindall & Cox, 1936. 8s. net.)

THE fact that this excellent book, which is largely concerned with the chemical engineering aspects of waterworks operation in America, has gone into a second

edition in four years should be sufficient indication of its value. Some idea of the thorough revision of the book can be gained by saying that this edition contains two new chapters, one containing a short historical introduction and the other, by R. C. Bardwell, dealing with the chemistry of softening and types of softening plants. In addition, it should be mentioned that there are 53 more pages, 13 more figures and 44 more references.

Up till quite recently the chemical treatment of water supplies has been considered to be uneconomical owing to the difficulty in assessing the gain to the consumer not only in soap, etc., by softening but also in the reduction of corrosion by hydrogen-ion control. It is stated in the book that the reduction in hardness of only 70 parts per million would save sufficient soap to offset the expenses of treatment. A new nomograph is also included for the regulation of corrective treatment for corrosion.

M. B. DONALD.

Ions in Solution. By R. W. GURNEY, M.A., Ph.D. [Pp. vi + 206, with 45 figures.] (Cambridge: at the University Press, 1936. 10s. 6d. net.)

DR. GURNEY'S book is essentially a theoretical survey of an old subject from a different point of view. He directs attention to the energies of ions, making use of the modern conception of electronic energy levels as envisaged by the quantum theory. The mathematics is easy and the co-ordination of the various parts of the field on this basis is both interesting and valuable. The influence of the solvent is considered, although the author might have pointed out that the experimental results on solvation hardly justify such assurance, and the theory of Debye and Hückel on ionic interaction is given a neat derivation. The discussion of the relation between electrode potential and metallic contact potentials has hitherto made little appeal to the practical worker, since there has been an awkward gap in which the effect of ion concentration in solution has been neglected. This is the essential core of the subject from the experimental point of view, and the world's laboratory workers have turned a deaf ear towards theoretical discussions which, however elegant and logical, have paid little attention to realities. Dr. Gurney has proceeded some way across this gap, and if the progress can be continued, as he hopes, his sketch will have been well worth while. Experimental electrochemistry is, however, very exacting. The name of the author guarantees clear and sound treatment, and the book is one which chemists will heartily welcome and will enjoy reading.

J. R. P.

Die Chromatographische Adsorptionsmethode. Grundlagen, Methodik, Anwendungen. Von Dr. L. ZECHMEISTER und Dr. L. v. CHOLNOKY. [Pp. xi + 231, with 45 figures.] (Wien: Julius Springer, 1937. R.M. 14.40.)

THE method of chromatographic analysis originated by the Russian botanist Tswett in 1906 has in recent years been taken up anew and in the hands of a numerous band of workers has been found to yield such valuable results that its applications are being continually extended, and a book such as the one under review is very timely. The first two chapters dealing with underlying principles and methods respectively constitute together the general part of the book; the special part composed of three chapters deals with applications of

the method to (1) natural pigments, (2) artificial pigments, and (3) colourless and slightly coloured substances. This latter chapter gives an account of the lesser-known applications of the method to a variety of substances which include aliphatic and hydro-aromatic compounds, benzene derivatives, polycyclic hydrocarbons, alkaloids, enzymes, etc., vitamins, hormones and other substances. It may be seen from the above recital what an unsuspectedly wide field of application this new method offers to the research worker. A new method of technique which is fruitful of results in one field naturally invites trial in others as well; thus the method which depended originally for its application upon the different colour of the variously adsorbed substances has been applied to colourless substances; various devices have been employed for rendering the colourless fractions visible; one of the most ingenious of these is to examine the column in ultra-violet light. The book, which gives a list of some 306 to 400 references, will be found invaluable to all those who wish to obtain a comprehensive account of the various successful applications of this method and of the experimental technique by which these are achieved. For those who have not had practical experience of the method a series of photographs of actual chromatograms are provided, and these give a very vivid impression of the appearance of the columns obtained.

P. H.

A Textbook of Organic Chemistry. By DR. JULIUS SCHMIDT. English edition by H. GORDON RULE, Ph.D., D.Sc. Third edition. [Pp. xxiv + 865.] (London: Gurney & Jackson, 1936. 25s. net.)

SCHMIDT'S *Organic Chemistry* has been deservedly popular as a text-book for university students and there seems every prospect of a continued demand, as of its kind it is one of the best. The new edition is some twenty-one pages longer than the last; the main additions are in the fields of stereochemistry, the structure of polysaccharides, chlorophyll, hæmoglobin, the vitamins, sterols, bile acids and sex hormones. One cannot but feel that Dr. Rule is giving way to temptation in introducing popular topics. This policy is beset by dangers. Firstly, views change rapidly; for example, the structure given for vitamin B₁ has already been superseded. Secondly, an impression of modernity is conveyed which would be better deserved if the more everyday topics were brought up to date; for example, if the manufacture of *r*-malic acid from benzene, of aniline from chlorobenzene, and *n*-butyl alcohol from acetaldehyde were mentioned; again in the description of the manufacture of acetic acid, twenty lines are devoted to the vinegar process, twenty-five lines to wood distillation, and but four to the synthesis from calcium carbide. Thirdly, the book grows until the publishers feel justified in increasing the price, already high for undergraduates.

The value of the book is that it presents clearly the experimental facts of organic chemistry that every honours student should know. Beyond these there is a field so vast that no student can plough all of it, and they should look for guidance from their teachers what parts they should labour in; the sex hormones and such-like belong to this region and information on them is better sought in specialised monographs. The process has not gone far as yet, and it will be a great pity if future editions are spoilt by becoming overloaded with specialised branches of organic chemistry.

O. L. B.

Organic Chemistry. By L. J. DESHA. International Chemical Series. [Pp. xvi + 750, with 53 figures.] (New York and London : McGraw-Hill Publishing Co., Ltd., 1936. 21s. net.)

THIS is very definitely a book intended for getting students through examinations. Even at the end of the first chapter (20 pages), the reader is offered 22 questions. Still, there is a lot to be said for this method, of making beginners face up to their ignorance. As one reads the book, one is more and more impressed with the amount of material dealt with. The solid facts of organic chemistry are treated with great thoroughness, but in addition there are excellent accounts of subjects about which many text-book writers have not bothered to inform themselves. For example, there is a very satisfying description of the chemistry of petroleum.

The necessary little bits of physical chemistry are presented in a straightforward manner and not as magical exits from chemical difficulties.

In spite of its directness, the book does not thrust benzene at the reader at the beginning of a "Part II. Aromatic Chemistry," but leads him gently to it by way of cyclohexane: it appears first as cyclohexatriene.

The idea one gained on reading the first chapter remains with one to the end. The more important substitution reactions of toluene are set out in the sometimes scoffed-at "chart" form: the author knows how organic chemistry is most easily and indelibly learned. He has spared the reader from what a veteran has dubbed "oughts and crosses," and has produced a book for students who wish to learn facts and plenty of fundamental theory.

It is a pity that the industrial chemistry of the United States is not our own in matters of a little more than detail, and that the nomenclature of the American chemists is appreciably different from ours. Nevertheless, the book can hardly fail to be a success in English-speaking countries.

E. E. TURNER.

An Introduction to the Preparation and Identification of Organic Compounds. By ROBERT D. COGHILL and JULIAN M. STURTEVANT. [Pp. xiii + 226, with 24 figures.] (New York and London : McGraw-Hill Publishing Co., Ltd., 1936. 10s. 6d. net.)

THE first half of this manual contains an excellent chapter on important laboratory operations, with clear explanations of the underlying physico-chemical principles, followed by a well-chosen list of forty-two straightforward preparations. The rest of the work is devoted to qualitative organic analysis—since the authors maintain that "in identifying a number of unknown substances and preparing derivatives from them, a student is brought into contact with many more reactions than would have been possible had he spent the same amount of time in making routine preparations." A preliminary discussion of the chemistry involved in the reactions being studied is included in each section of the work. The technique of handling small quantities of materials is illustrated and appropriate weights and volumes of substance and reagent are always given. The scheme for tentative identification of an unknown is followed by a very useful chapter on the preparation of derivatives starting with from one-tenth of a gram to two grams of material. Most teachers would agree that the use of analytical "tables" by students tends to atrophy their deductive faculty and to foster a blind reliance on printed schemes. On these grounds one must criticise the arrangement in Chapter VI of a set of tests with key to be used with a selected list of between three and

four hundred of the commoner organic compounds. This is, in miniature, the system of qualitative organic analysis worked out on a more comprehensive scale by Mulliken in 1905 for the expert analyst—it is not, in the opinion of the reviewer, suitable for beginners. The text contains a few departures from standard English practice, e.g. p. 9, line 5, "Grades on experiments"; line 21, "0.074 the amount"; line 27, "labeled"; p. 36, line 8, "to insure intimate mixing"; pp. 51–2, "cookbook"; pp. 133 and 224, "elementary tests." Misprints occur on p. 6, line 1, "benzene" for benzine; p. 65, Fig. 22, "diethyl ethyl" for diethyl ether.

Apart from these minor blemishes, the book is beautifully printed, nicely bound in a handy size and, at its moderate price, forms an attractive introductory *praktikum*.

W. D.

Practical Organic Chemistry. By F. G. MANN, Sc.D., D.Sc., F.I.C., and B. C. SAUNDERS, M.A., Ph.D., B.Sc. With a foreword by SIR WILLIAM J. PORE, K.B.E., F.R.S. [Pp. xiv + 403, with 66 figures.] (London, New York, Toronto: Longmans, Green & Co., 1936. 8s. 6d. net.)

It is a pleasure to review so carefully planned and skilfully executed a book as this. It is based largely on the authors' experience in teaching the subject to very large classes of students at Cambridge University, under conditions which make economy in materials and time essential. The experimental work has been carefully checked with this end in view, and the directions are clear and very detailed. An excellent feature is the provision of a brief theoretical commentary on the various reactions.

The scope of the book is to cover Part I of the Natural Science Tripos at Cambridge, the General London B.Sc., and the Pass Degrees of other Universities. It is therefore essentially a first practical book in organic chemistry and can be used by students reading for the M.B. and Higher Certificate Examinations.

The book opens with a section on manipulation which gives exact instructions for the principal laboratory operations, and covers fully the points on which so many students go astray. Then follows the main section of some 160 pages on preparations, and shorter parts dealing with reactions and identifications, and with quantitative analysis generally. Finally, there is a short section on enzymes and a very useful appendix.

A few comments on points of detail may be made: It would be convenient for reference if a list of the preparations were included at the beginning of Part II. The page heading on the right-hand pages of Part III should surely be "Reactions and Identifications" and not "Organic Compounds." The section on the separation and identification of organic compounds (p. 264 *et seq.*) suffers from over-compression, and is below the high standard of the rest of the book.

The book can be cordially recommended to both teachers and students.

R. P. L.

The Aromatic Diazo Compounds and their Technical Applications.

By K. H. SAUNDERS, M.A., F.I.C. With a Foreword by PROFESSOR A. G. GREEN, F.R.S. [Pp. xii + 224.] (London: Edward Arnold & Co., 1936. 12s. 6d. net.)

THE immense importance of the Griess reaction in the organic chemical industry, in particular for the manufacture of azo dyes, has made it rather

surprising that the late Dr. Cain's *Chemistry and Technology of the Diazo Compounds* has never been brought up to date. Possibly, however, the very magnitude of the task has acted as a deterrent.

Mr. Saunders has now very wisely preferred to strike out on his own and has produced a very satisfactory summary of the present state of this branch of chemical technology.

As Professor Green states in his "Foreword," no other reactions in organic chemistry exhibit such an extraordinary versatility and generality as the diazo reaction. No other series of chemical changes occur with such quantitative accuracy, ease and rapidity as those of which diazo compounds are capable.

When it is remembered that 80 per cent. or more of the dyes and lakes of commerce owe their formation in one way or another to the diazo reaction, the debt of science and of industry to the discoveries of Peter Griess, the brewer's chemist of Burton, become even more impressive.

The treatment of the subject may best be gauged from the chapter headings: The formation of diazo compounds; Stabilised diazo compounds; Elimination and interchange of groups in diazo compounds; Theory of the diazotisation reaction; Reactions of the diazo compounds; Action of light on diazo compounds; Theories of constitution of the diazo compounds; Author Index; Subject Index.

The large number of references to the literature enhances the value of the book and increases our debt to the author; a study of the book will suggest many useful lines for further research.

There are a few slips and misprints here and there but they are mostly obvious. One may regret that it has not been possible to include a longer account of the early history of the diazo reaction at the hands of Griess; perhaps this might be included in a later edition.

It is almost needless to add that the book is well and clearly printed, and it is sold at a price which should ensure it finding a place in all chemical libraries.

F. A. M.

Enzyme Chemistry. By HENRY TAUBER, Ph.D. [Pp. xii + 243, with 28 figures.] (New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd., 1937. 15s. net.)

A SCIENTIFIC book must be judged largely from the point of view of those for whom it is written; a students' text-book must pass certain tests whilst a specialist's monograph has to be exhaustive and critical. Between the two types there is need for works which contain a readable account of a specialised subject so that workers generally can profit from it without difficulty. The book before us is of this type; it is of American origin, where the greatest interest is taken in biochemistry by the medical profession.

The subject of enzyme chemistry is now very much to the front. The proof at long last that many enzymes are proteins, or at least consist of an unknown prosthetic group associated with a protein, and the isolation of some of them or their precursors in crystalline form, have attracted renewed interest to the group. The pages in the book on which the details of the preparation of these crystalline enzymes are described and the micro-photographs of them record what is in fact a remarkable achievement associated for all time with the name of Northrop.

The enzymes are broadly of two classes, those which affect hydrolysis, which are conveniently classified according to the substrate on which they act, and those which accelerate oxidation and so enable inert stable substances to be changed into readily oxidisable compounds *in vivo*. These are associated with other substances termed "co-enzymes" for special reactions, so that the complete change often involves a number of factors all acting in sequence but each of which is necessary. The elaborate mechanism enables the organism to exercise a very delicate control over its reactions. These oxidising enzymes also apparently consist of protein and a prosthetic group which is inactive when alone, so they must be ranked as true enzymes.

Though we have some clue to the chemical structure of the vitamins, the manner of their action is still obscure. They are not enzymes but they may be one factor and an essential one in an enzymic change. The great complexity of alcoholic fermentation, the number of factors involved and stages traversed, the rôle of phosphoric acid both inorganic and organic in the reaction, are evidence of the great complexity *in vivo* of what the chemist writes as a simple reaction.

The author has given a very readable account of the enzymes freed from elaborate detail, practical as opposed to theoretical in character, and stimulating enough to make the reader wish to go further, for which purpose there is provided an adequate list of references to the original literature at the end of each chapter.

E. F. A.

A Textbook of Applied Biochemistry. By F. WOKES, B.Sc., Ph.C., F.I.C. [Pp. ix + 522, with 79 figures, including 3 plates.] (London : Baillière, Tindall & Cox, 1937. 15s. net.)

THE primary object of this book is to supply to pharmacists and to pharmaceutical students that knowledge of Biochemistry which is nowadays essential for proficiency in their profession—and incidentally for success in their Diploma examinations. It might be thought, therefore, that it would be a dull text-book of somewhat limited interest. But this is not so ; it is in no way dull, and all kinds of interesting subjects are discussed within its pages, for the pharmaceutical chemist occupies a key position in our modern society. He sells patent medicines and cosmetics, he develops photographs, he chloroforms unwanted kittens, he advises the public on minor ailments and accidents, and incidentally he may dispense prescriptions. Insulin and rouge, infant foods and laudanum—all may be purchased at the chemist's. And so there seems to be no end to the variety of topics discussed in this book. We come across interesting discussions of the methods of drying milk, of the use of dried grass in agriculture, of the principles of the biological assay of drugs, of spectroscopy and colorimetry, of the methods of producing and measuring ultra-violet radiation, and of innumerable other subjects. Nor must it be imagined that all this information is presented in a haphazard, confused manner. On the contrary, the book is carefully and cleverly planned, each chapter dealing with some general aspect of Biochemistry. Thus the first deals with the biochemical importance of water, the second with hydrogen ion concentration, the third with surface phenomena and colloids, and this is followed by chapters on light and ultra-violet radiation. Subsequent chapters treat of carbohydrates, fats and proteins, enzymes and bacteria, and finally of hormones and vitamins. The treatment is usually

elementary and simple, but the nature of the book, its emphasis on the practical, and especially on the pharmaceutical applications of the subject, results in the point of view being often novel and fresh. Some readers may be surprised at the amount of space devoted to subjects which at first sight seem rather remote from the sphere of the ordinary pharmacist. We do not usually think of him as an authority on spectrograms and spectrometers. However, the importance attached by the author to such subjects is easily understood when it is realised how much the newer optical methods are now used in the analysis and standardisation of drugs. In any case their inclusion makes the book all the more valuable to the general biochemical reader who will be grateful to have this compact and lucid treatment of a branch of biochemical technique which is ever becoming more and more important.

This book is certainly to be recommended to many outside the particular class for whom it was primarily written.

W. O. K.

A Practical Course in Agricultural Chemistry. By F. KNOWLES, F.I.C., and J. ELPHIN WATKIN, B.Sc., Ph.D., A.I.C. With a Foreword by SIR JOHN RUSSELL, D.Sc., F.R.S. [Pp. x + 188, with 21 figures.] (London: Macmillan & Co., Ltd., 1937. 10s. net.)

THE authors have set out to prepare a book containing the optimum amount of practical chemistry required by students reading for Degrees and Diplomas in Agriculture, Horticulture, Dairying and Poultry Husbandry. Recognising that a great deal, but not all, of the chemical laboratory work of these four subjects is common, the authors' intention has been to include the requirements of each subject so that a student in any particular subject may omit those exercises that are not relevant to his studies. The authors have achieved their object admirably and the book should find its way into all institutions in the country in which practical agricultural chemistry figures in the curriculum. The ground is very well covered. The first chapters deal with Soils and Fertilisers and are followed by those on Biochemistry, Feeding Stuff, Dairy Products, Water, Insecticides and Fungicides. The description of alternative methods adds to the value of the book.

Each chapter begins with very good explanatory matter, and as Sir John Russell says in the Foreword a large part of the value of the explanations lies in the way they relate each piece of work to the subject as a whole.

A course in practical agricultural chemistry often tends to become nothing but analysis. It is therefore pleasing to see the inclusion of such exercises as the oxidation of ammonia, the laboratory preparation of superphosphate and others that are intimately associated with the lecture-room work.

The methods of preparing reagents are given in an Appendix.

N. M. C.

Perfumes, Cosmetics and Soaps: With especial Reference to Synthetics. Vol. II: *A Treatise on the Production, Manufacture and Application of Perfumes of all Types.* Vol. III: *A Treatise on Modern Cosmetics.* By WILLIAM A. POUCHER, Ph.C. Fifth edition. [Vol. II: pp. xvi + 426, with 83 figures, including 63 plates; Vol. III: pp. xii + 228, with 2 plates and 1 figure.] (London: Chapman & Hall, Ltd., 1936. 25s. and 21s. net.)

THE first volume of this treatise was reviewed in *SCIENCE PROGRESS*, Vol. XXXI, p. 568.

The two volumes under review cover the same ground as was covered in the previous edition by a single volume, but the two books together contain some 150 pages more. This increase in size is due to the incorporation of a good deal of new matter and in some cases almost rewriting of certain sections ; this applies notably in Vol. II to the monograph on roses, which, as a result of the author's visit to Bulgaria, has been doubled in size.

In the third volume on Cosmetics two new chapters have been added on *Rouges and Eye Cosmetics* and on *Sunburn Preparations*, and in accordance with the demand of the times the chapter on *Lipsticks* has been rewritten.

A feature of the new edition is that all the formulæ given are numbered consecutively and reach the goodly total of 2383. It will be seen that the three volumes together contain a very considerable amount of information not easily procured from other sources, and all interested in the subject of Cosmetics, etc., will be indebted to the author for producing such a readable book, so attractively got up and plentifully supplied with excellent illustrations.

P. H.

GEOLOGY

Engineering Geology. By H. RIES, Ph.D., and THOMAS L. WATSON, Ph.D. Fifth edition. [Pp. viii + 750, with 88 plates and 271 figures.] (New York : John Wiley & Sons, Inc. ; London : Chapman & Hall, Ltd., 1936. 25s. net.)

THIS latest revision of a well-known work, last issued in 1931, is very welcome to both students and teachers of civil engineering. Chapter 1 deals with the elements of mineralogy, and it is noted that Figs. 1 to 7 have reference letters shown on them which are not described in the text ; it is a question whether engineers need these figures, and those of a similar nature given later in the chapter. The photomicrographs given are large and informative, and one would like to see more of them used to illustrate recent applications of the microscope to engineering problems. Chapter 2, dealing with rocks, is extremely lucid, but it is thought that p. 170 of Chapter 3 might be amplified with advantage. It deals with the effect of structural features on quarrying operations, and this topic is of great importance to civil engineers, many of whom have to work quarries. It is also considered that a few simple worked examples on the graphics of folding and faulting problems would be of more use to the reader than applications of mathematics to this branch of the science—always a doubtful proceeding. The chapters which follow cover weathering, surface and sub-surface waters very thoroughly, and the purely geological portion may be said to take about two-thirds of the book, up to p. 484.

Chapter 12, in describing building stones, omits to mention the dangerous minerals chlorophaeite and montmorillonite, although work on the latter mineral has been done in the United States by G. F. Loughlin, of the U.S. Geologic Survey, while the recommendations of our own Building Research Station as to the prevention of stone decay, simple though they are, could have been included with advantage. It is very encouraging to read an opinion from another country that chemical analyses of road and building rocks are of little significance without detailed mineralogical and chemical knowledge for their correct interpretation.

Chapters 15 and 16 deal with coal, petroleum and natural gas, and it is perhaps questionable whether these highly special subjects are necessary

in a volume of this kind. The same remark applies also to the later chapter on Ore Deposits.

Chapter 17, on Road Foundations and Materials, is of the high standard expected from a country which has for long been a pioneer in research on this subject; a minor criticism is that the slipperiness of "trap rock" under traffic when used as sett paving is not dealt with.

The concluding chapter on Historical Geology is of just the right length, and in the best possible place for the reader, and one can conclude with an appreciation of the good style of production of the volume and an expression of regret that we have not available to us a similar book dealing more particularly with British conditions and practice.

B. H. KNIGHT.

La Géologie et les Mines des Vieilles Plateformes. By F. BLONDEL.
[Pp. 303, with 59 figures.] (Paris: Société d'Éditions Géographiques, Maritimes et Coloniales, 1936. Frs. 36.-)

THIS is another remarkable volume emanating from the energetic *Bureau d'Études Géologiques et Minières Coloniales*, the earlier publications of which have been reviewed in *SCIENCE PROGRESS* (Jan. 1935, p. 565; Jan. 1936, p. 566; July 1936, p. 177). The book is the outcome of a series of conferences which were held at the Paris Museum of Natural History during 1934 and 1935, the object of which was to facilitate the geological and mining exploration of French overseas possessions. The majority of these colonial regions are situated in Africa, a continent which largely consists of an enormous "ancient platform" or shield. The author, F. Blondel, chief mining engineer of the Colonial service, begins by defining the "ancient platforms" as those zones of the earth's crust which have been stable since the beginning of Cambrian times. These regions commonly consist of a crystalline basement of folded and metamorphosed sediments and volcanic rocks, invaded by great masses of granite which have also been metamorphosed into gneiss. This crystalline basement is usually covered by a later Pre-Cambrian series of sediments and volcanic rocks which are non-metamorphic and not affected by serious folding, and by even later series of the same nature. The author reviews the geological constitution of those regions of the globe which, like Africa, answer to this definition; and this is a very useful, succinct contribution to comparative regional geology. The associated problems of metamorphism, of conditions of sedimentation in continental terrains, and of special tectonics of the "ancient platforms" are then successively treated.

The second part of the book deals with the minerals of the "ancient platforms." The conclusions that M. Blondel comes to are too many and too complicated to be fully recounted here: but it seems from an informative diagram (p. 265) that the crystalline basement is very poor in minerals, except graphite; that the "semi-metamorphic series" associated with it is rich in mica, diamond, nickel, chromium, manganese and iron; and that the non-metamorphic "série de couverture" is, above all, rich in gold, and notably rich in diamond, cobalt and petroleum.

The book is well written in the usual lucid French style, and well illustrated with diagrams, sections and maps. A good modern bibliography and very full geographical and subject indexes are provided. An unusually large amount of comparatively inaccessible data is here brought together and presented in an easily assimilable form.

G. W. T.

Congrès International des Mines, de la Métallurgie et de la Géologie Appliquée. VII^e Session, Paris, 20-26 Octobre 1935. [Tome I: pp. viii, 1-528; Tome II: pp. viii, 528-1088.] (Paris: Section de Géologie Appliquée, 1936. Frs. 120.-)

IN these two massive quarto volumes the papers presented to the Section of Applied Geology at the above International Congress are presented, with very numerous illustrations, including maps, diagrams and plates which are not numbered consecutively. The first volume contains 24 papers on ore-deposits of magmatic origin; 17 on ore-deposits of sedimentary origin; and 19 on petroleum. The second volume contains 5 papers on applied geology in public works; 5 on applied geology in agriculture; 5 on hydrology; 10 on geophysics; 15 on methods of teaching and research institutes; and, finally, 6 collected papers on applied geology in the Portuguese colony of Mozambique. As the communications come from thirty-two different countries, although France and the French Colonies are naturally most abundantly represented, there is in these two fine volumes a wealth of material on the economic geology of the whole world, much of it otherwise rather difficult of access. Although there is a full list of contents, the lack of a general subject index somewhat detracts from the usefulness of the work. While it is, of course, impossible to refer to individual papers, we notice, however, that French geologists include a very wide genetic range of ore deposits under the term "Gisements d'origine magmatique," for, in addition to metalliferous veins, impregnations, etc., which may have a more or less remote connection with igneous rocks, there are included under this heading papers on alluvial gold, diamonds, zircon, and sedimentary ores of iron.

G. W. T.

BOTANY AND AGRICULTURE

An Introduction to the Principles of Plant Physiology. By W. STILES, M.A., Sc.D., F.L.S., F.R.S. [Pp. viii + 615, with 5 plates and 55 figures.] (London: Methuen & Co., Ltd., 1936. 27s. 6d. net.)

A GENERAL account of the principles of plant physiology in English of not too advanced a character has long been a desideratum, and Prof. Stiles in the present volume has furnished an account that is not only well balanced but clearly written, in a manner that should meet the needs of most students.

The subject-matter is divided into four sections, of which the first deals with the general physiology of the plant cell (pp. 7-158); the second treats of metabolism (pp. 159-304); the third of the physiology of development, germination and reproduction (pp. 305-420); and the fourth is concerned with irritability and movement (pp. 421-544). The bibliography of papers to which reference is made in the text is naturally a selected one, but the fact that it occupies 40 pages indicates that it is of a fairly comprehensive character.

An appreciation of physiological principles is an essential requisite, whatever may be one's particular direction of approach to the study of plants, and from the treatment in this book the student who is not a physiologist should be able to apprehend the fundamentals involved.

E. J. S.

British Trees and Shrubs, including those Commonly Planted.

By H. GILBERT-CARTER, M.A., M.B., Ch.B. [Pp. xvi + 291.] (Oxford : at the Clarendon Press; London : Humphrey Milford, 1936. 12s. 6d. net.)

It will be difficult, I think, for anyone to condense into a given space, in this book about three hundred pages, more information than Mr. Gilbert-Carter has been able to do in this recently published work. The title it bears does not mean that the author has confined himself to the consideration of native species only. He tells us that the intention of writing the book first arose from the ignorance manifested by his students of common plants in villa gardens. If we exclude the unbridled species-making of the specialists in *Rosa* and *Rubus*, the number of genuine species of woody plants native of the British Isles is not really very large. Except in quite rural parts, the trees and shrubs we see in our walks abroad are predominantly of exotic origin and the value of this book is in the descriptive notes it furnishes of practically all of them, and, equally important, very considerable help in identifying them.

If one were in a carping mood it might be wondered why scarcely known genera like *Calycotome* and *Cercocarpus* are given the distinction of large capitals whilst *Rhododendron luteum* (the yellow azalea), one of the most important flowering shrubs ever introduced, gets no description and only very brief mention. But the work as a whole is so full of exact information, contains so many interesting notes, is so admirably printed, and is so handy for one's coat pocket, that criticisms of that kind may seem ungracious.

An admirable innovation in works of this type and one which will be very much appreciated is giving the origin and meaning of all the generic and specific names mentioned; this information is conveniently given in the form of footnotes to the page on which they occur. Very useful also, as an indication to proper pronunciation, is the accentuation of their vowels.

In regard to nomenclature, the author adopts the International Rules but remarks that the law of priority often defeats their main object, which is the "fixity of names." He suggests a list of specific *nomina conservanda* which seems to be a modest and reasonable proposal, but successive botanic conferences have turned it down.

W. J. B.

Growth Hormones in Plants. By P. BOYSEN JENSEN. Translated and revised by GEORGE S. AVERY, JR., and PAUL R. BURKHOLDER. McGraw-Hill Publications in the Agricultural and Botanical Sciences. [Pp. xiv + 268, with 64 figures.] (New York and London : McGraw-Hill Publishing Co., Ltd., 1936. 21s. net.)

PLANT Hormones represent a field of investigation which within the last decade has undergone a phenomenal expansion, and has aroused the interest alike of biologists and biochemists. The author of this work was himself a pioneer in the field, and has made contributions of the greatest importance to the subject. It is therefore particularly gratifying that he should have undertaken the task of presenting a survey of the present position with regard to this wide and complex study. In the original German edition of *Die Wuchsstofftheorie* two hundred individual papers were dealt with, and the translators have added a further two hundred citations, bringing the literature to date up to the end of 1935. The progress of the investigation is dealt

with historically, so that the book presents a fascinating picture of the origin and development of a scientific discipline which cannot fail to have a very high educative value.

The scope of the work is restricted to a very full discussion of the functions of auxine and heteroauxine in relation to growth and tropic reactions, but a supplementary bibliography is appended in which work dealing with other hormones is to be found. The vast body of information dealt with is presented with the utmost clarity, and is profusely illustrated. Besides the historical survey, the detection and quantitative determination of growth substances, their preparation, occurrence and transport in the plant, are dealt with. Their significance for normal growth and differentiation, phototropic, geotropic and traumatic curvatures, each form the subject-matter of a separate chapter. Each of the ten chapters ends with a summary of the contents in which the salient points are emphasised.

For the student desiring to acquaint himself with the facts, no better book could be recommended, while for the research worker attracted to this field the full bibliographies give access to every aspect of the investigation. Precise information is given on practical details of technique which is invaluable.

Not the least important feature of the work are the indications of uncertainties of knowledge and the lines which further progress must pursue, so that this book is stimulating as well as informative.

The work in translation has lost nothing of the original and has indeed gained by the collaboration. The translators in making Professor Boysen Jensen's work accessible to the English-speaking world have rendered a great service to students and research workers alike.

F. G. G.

An Introduction to the Scientific Study of the Soil. By NORMAN M. COMBER, D.Sc.(Lond.), A.R.C.S., F.I.C. Third edition. [Pp. vii + 206, with 25 figures.] (London: Edward Arnold & Co., 1936. 7s. 6d. net.)

MOST books dealing with the soil as a whole tend to supply too much information and so make it difficult to "see the wood for the trees." This little book, however, does not suffer from this disadvantage and provides instead an excellent summary of the subject for the general reader as well as for the students for whom it is written. The present edition does not differ materially from the preceding one and has the merit of retaining an account of the theories which have been held in the past regarding the composition and nature of humus, and the explanations offered for the flocculating action of lime upon soil colloids and the movement of soil water; at the same time the author has not failed to describe the newer ideas which are developing in connection with these subjects and by boldly facing difficulties or anomalies he helps to remove them. A new feature is the introduction of the conception of capillary potential pF . The book may be confidently recommended as a clear and able synopsis of a very extensive subject.

P. H.

BIOLOGY

Biology in the School. By H. ALAN PEACOCK, M.Sc. [Pp. xvi + 354.]
(London: William Heinemann, Ltd., 1937. 10s. 6d. net.)

THE author of this book is highly to be congratulated. It is safe to say that it should be in the hands of *all* whose business it is to teach biology in schools. Those, and these are many, who are not yet in their stride as biology masters, or mistresses, will find it an invaluable help and guide. On the other hand, experienced teachers will consult it with much profit to themselves. Again and again the present reviewer has come across points wherewith he often had difficulties as a teacher, and almost invariably found them acknowledged, and wise advice given on how to deal with them.

The book is written in a lively style, and it shows its author to be not only an up-to-date biologist, but a man of humour, tolerance and breadth of view.

After a welcoming foreword from Sir John Russell, come the preface and introduction; neither of which should remain unread. Next is given a short history of science in general and of biology in particular in schools, and the pioneer part played by the older Public Schools is duly acknowledged.

Mr. Peacock fully believes in the great importance of his subject, and if there still linger in some unregenerate quarters doubts as to the desirability of teaching biology in schools, a perusal of Chapters III and IV should easily dispel them. Incidentally Chapter XI should be read by all headmasters. The author is strongly against any "sex-bias," but holds that biology teaching is naturally the best method of attacking the difficulty, and his advice thereon is wise and timely.

Biology as an examination subject is fully treated: the almost limitless avenues of approach it holds out are duly noted: and the book deals exhaustively with possible and actual examination syllabuses. His own particular child is the "Physiological syllabus," and many teachers will agree that this, or something like it, is probably calculated to give the best results. Especially valuable are the author's suggestions for "short-service" biologists, to wit, boys and girls who have had some preliminary training in chemistry and physics, and want some biology to finish up with.

He next deals with VIth Form work, boys who are preparing for such examinations as the H.S.C., First M.B. and so on; and in Chapter VI there is given a course for non-specialists, who will leave school at 18 or 19, during their last year, and this should be exactly what is required.

Two chapters are devoted to the School Library, Museum, and Natural History Society, and the rest of the book, roughly half, is concerned with the technique of teaching. This part of the subject is dealt with exhaustively, and a mass of valuable information provided ready to hand.

Small criticisms can of course be made. We are not told, for instance, how *Amoeba* may be induced to feed at the proper moment when somebody is looking down a microscope: the value of *Gammarus* for experimental breeding seems to be omitted: some would like to know the best method of preparing microscopic slides to show mitosis in animal cells; and how the particular difficulties in arranging water cultures may be overcome. But such omissions are inevitable in any book of the kind, and in no wise detract from its value. On the other hand, such traps as the structure and working of the frog's heart are objects of special notice and warning.

There is an ever-growing demand for the teaching of biology in schools,

and at present the supply of teachers is inadequate. It is safe to say that many young men and women, already science teachers, are eagerly engaged in seeking knowledge, help, and guidance to grapple with a difficult subject. This book should be of real value to them in their quest.

M. D. HILL.

MEDICINE

Grundriss der vergleichenden Physiologie. Vol. I: Physiologie der Sinnesorgane und des Nervensystems. By W. von BUDDENBROCK. Second edition. [Pp. viii + 567, with 355 figures.] (Berlin: Gebrüder Borntraeger, 1937. RM. 42.- bound; RM. 40.40 paper covers.)

SINCE its appearance nine years ago von Buddenbrock's *Grundriss* has been the most generally useful text-book of comparative physiology. Written primarily as an introduction for students it is constantly referred to by advanced workers. A second edition of this work is now in course of publication. But although the title remains the same it is in effect a new book. It is to appear in three volumes, and the first, which is here reviewed, is by itself almost as large as the single-volume first edition. Indeed, the whole character of the work has been fundamentally altered. It is no longer an introduction, but aims rather at being a complete account of the present state of knowledge in comparative physiology. The first volume deals only with the sense organs and nervous system—a difficult beginning, which the author defends on the grounds that in physiology it is immaterial where you begin: life is all of one piece. A knowledge of general physiology and of the essentials of mammalian physiology is assumed, and the reader finds himself from the outset in the midst of current controversies. In short, this book is not such easy reading as its predecessor. But it is thoroughly alive; the material is critically set out and held together by the ideas and opinions of the author; and it has not degenerated (as such comprehensive works by German authors sometimes do) into a mere patchwork of undigested fact. By his own admission the author has given most space throughout to the invertebrates, and where almost no information exists on a given system outside the vertebrates, as is the case with the autonomic nervous system, it has been omitted entirely—until a later edition. So far as can be judged by a single reader the text and the copious bibliographies appear astonishingly complete, particularly on invertebrate physiology. The book will therefore be in constant demand by the research worker and should prove even more valuable than the first edition.

V. B. WIGGLESWORTH.

Handbook of Physiology and Biochemistry. By the late W. D. HALLIBURTON, M.D., LL.D., F.R.C.P., F.R.S., and R. J. S. McDOWALL, M.D., D.Sc., F.R.C.P.(Edin.). Thirty-fifth edition. [Pp. xii + 973, with 4 coloured plates and 373 figures.] (London: John Murray, 1937. 18s. net.)

LESS than two years have passed since the thirty-fourth edition of McDowall's *Handbook of Physiology* appeared. The thirty-fifth edition which has recently been published follows essentially the lines of its predecessor, thus retaining the excellent features initiated by McDowall in the previous edition. Minor but necessary changes have been made in many chapters, the text revised,

illustrations removed or replaced by new ones in order to incorporate as far as possible recent advances. The general result has been to add to the usefulness of a text-book which supplies in many ways the examination requirements of the medical student without being too cumbersome or overloaded with discussion based on evidence essentially indirect and therefore liable to confuse the elementary student in physiology, *i.e.*, the medical student.

While the text changes are essentially sound, the change in the title (addition of "and Biochemistry") hardly appears justified.

The successive appearance of new editions of different physiological text-books published in Britain in 1936-37 has now assumed the appearance of a "publications" race. The reviewer is firmly of opinion that the incorporation of recent work in physiology in physiological text-books might with advantage be delayed for at least five years after communication or publication in scientific journals until adequate confirmation is forthcoming and a proper perspective in regard to new work is attained. If this were done authors of physiological textbooks might feel disposed to consider five years also as a suitable interval between successive editions.

C. R.

The Metabolism of Living Tissues. By ERIC HOLMES, M.A., M.D.
[Pp. x + 235.] (Cambridge: at the University Press, 1937. 7s. 6d. net.)

THE branch of biochemistry with which this short book deals is dynamic in more senses than one and the author is to be congratulated on his courage in attempting the treatment of such a rapidly developing subject in a small monograph.

The conversational and at times somewhat journalistic style in which the book is written will be an attraction to some readers and an irritation to others. More serious, however, is the fact that the effort to avoid heaviness of treatment, admirable in itself, has led in parts of this book to a superficiality which is hardly conducive to the acquisition of sound knowledge; this is the more surprising since the book is apparently designed for the use of students in the early stages of their acquaintance with biochemistry.

This criticism applies least to the chapters dealing with subjects in which the author has been personally interested, such as those on the intermediate metabolism of muscle and nerve; these are admirable in the clarity with which they unravel a complex mass of observations. The impression left by other sections of the book is less favourable, however; the treatment of hormones and vitamins for instance is so slight as to be of little value, and is not strengthened by the inclusion of numerous structural formulæ without adequate chemical discussion.

A difficulty inherent in the writing of a book of this type, and one which the author has been unable to avoid, is the decision as to the amount of previous knowledge to be assumed; it is odd to find for instance (p. 40) that a parenthetic statement of Avogadro's hypothesis is considered necessary whilst a few pages later the reader is expected to be able to appreciate the structure of Warburg's yellow pigment.

In spite of some faults, however, the book does achieve an originality and freshness in the mode of presentation of the subject which are to be welcomed; provided that it is read after a preliminary study of descriptive

biochemistry it should prove of considerable value to students who find it difficult at present to obtain a clear account of the subjects with which its best chapters deal.

C. R. HARRINGTON.

Blood Cultures and Their Significance. By HILDRED M. BUTLER, B.Sc. Monographs of the Baker Institute of Medical Research, No. 3. [Pp. xiv + 327, with 3 plates.] (London: J. & A. Churchill, Ltd., 1937. 15s. net.)

THE author, who is bacteriologist at the Baker Institute of Medical Research, Melbourne, introduces her subject with a warning and insistence that the results, positive or negative, of blood cultures cannot be interpreted or accepted unless the methods employed are given. In the past these methods have lacked for the most part any standard plan, and the results obtained in different laboratories are so diverse that to attempt their assessment is useless. In Chapter 2, the most valuable section of the book, is set out a detailed account of the simple technique employed and recommended as suitable in practically all cases that are encountered in general laboratory work, and which, if adopted, will do much to establish the true value of blood cultures, not only in the diagnosis of diseases, but also in prognosis, where until now the value of blood cultures has been greatly under-estimated; further, the importance of blood cultures as a guide to treatment has increased with the more widespread use of specific antisera.

The chief defect of this interesting book arises from the author's zeal for references, which are brought into the story of the text, often, we think, unnecessarily, and tend thereby to interrupt continuous reading. It is possible that by a more liberal use of footnotes and tables, and in some places curves, this might be in part overcome. As it is, the book is neither a text-book nor a convenient laboratory book of reference.

P. J.

The Natural History of Mind. By A. D. RITCHIE, M.A. [Pp. viii + 286.] (London, New York, Toronto: Longmans, Green & Co., 1936. 15s. net.)

THE human mind is probably Nature's latest and most daring accomplishment in organisation, and as such, even if there were not other reasons, it is an object of particular interest to study. Unfortunately we have only human minds to study it with, and the psychologist must at times feel something akin to the humiliation of the monkey attempting closer acquaintance with his reflection in the looking-glass. Prof. Ritchie, a philosopher who is also a front-rank physiologist, and one well acquainted with modern schools of psychology, stands away from the looking-glass and discusses the Natural History of Mind with a detachment seldom found in writers with possibly deeper but certainly narrower foundations for their opinions.

Stressing, naturally enough in a physiologist, the importance of regarding mind-and-body as one entity, Ritchie takes first the more material aspects of his subject, and describes the methods of hormonal and nervous control of the body, leading to a description of the nervous system as a whole, and to a discussion of the methods and results of the Sherrington school, with a description of Sherrington's conclusions as to the integrative action of the nervous system. There follows an account of the entirely different physio-

logical approach used by Pavlov, and a discussion of the applicability of the Conditioned Response to the problem of the nature of Mind. Ritchie's criticism is the simple but cogent one that the success of an experiment of Pavlov's type demands that all external and irrelevant stimuli must be absent: the animal's "mind" must be a blank. As a method of studying "mind" it is self-destructive.

The approaches used by the behaviourist, the psycho-physicist, the classical psychologist, the psycho-analyst, are examined with close scrutiny and none comes too well out of the examination, in so far as he claims to describe attributes of Mind. The psycho-physicist is learning much—but chiefly about sense organs and synapses. The psycho-analysts produce chiefly myths, but perhaps that is the right language for describing an illogical entity like the human mind. "It must be accounted to the psycho-analysts for righteousness," says Ritchie, "that they have not been afraid to make fools of themselves. The academic psychologists have been so anxious to be respectable and to be treated as real scientists that they have never dared let themselves go. The result has been that they have produced dull myths instead of exciting ones, but they have been myths all the same."

The book, which is well and accurately printed, is cast in the form of an introduction and eight chapters (modified considerably from some lectures given at Cambridge in 1935). A brief index is appended, but it is a waste of time. Many of the entries in it are piffling and some are positively comic in their fatuity.

The physiologist may learn no new physiology from this book, and the psychologist no new facts (if facts he wants), but anyone, physiologist, psychologist, philosopher, or man-in-the-street, who is interested in the nature and properties of Mind, will welcome Ritchie's balanced review of the several ways of approach to their subject which have been opened up.

P. EGGLETON.

Modern Discoveries in Medical Psychology. By CLIFFORD ALLEN, M.D., M.R.C.P., D.P.M. [Pp. x + 280.] (London: Macmillan & Co., Ltd., 1937. 8s. 6d. net.)

In the first page of this book the author reminds us of the old gibe at academic psychology as "the description of the perfectly obvious in terms of the unintelligible" and after reading this truly interesting, even entertaining, account of the progress of morbid (abnormal) psychology through the fairy lands of childhood, the totems of primitive people, the mysticisms of prophets, the entanglements of the conscious and the unconscious, the craving (libido) of sex and other aggressions, the confusion of love and hate, of projection and introjection and above all the curious personal interpretations of subjective symptoms by the protagonists of different schools of investigation, we feel that the gibe still holds good; and of necessity, for as yet psychology cannot aspire to scientific status. It is in the phase of collecting data, a stupendous array of variables, and there is no machinery by which they can be assessed or correlated, no yard-stick to measure them. Science cannot rely upon guessing and subjective feeling.

Apart from these considerations Dr. Allen has given us an excellent account of the different schools of psychological procedure. Of these the most outstanding is the Freudian school, dominated by the sex idea, responsible for the "Œdipus Complex," and the method of treatment known as

"psycho-analysis," which has perhaps given help to patients and contributed to the knowledge of psychic processes, but which is especially notorious for the persistent and virulent opposition it has received from the medical world. Following upon Freud came the school of Adler, a less unpleasant and saner school in which sex has no prominence and is replaced by "aggression"—the craving for a goal. It is certain that many neurotics can be cured by Adler's method of analysis which is simpler, quicker and probably less dangerous than Freud's method, which may be prolonged over years. Adler's methods are used by all who treat children for neurotic troubles, and it seems likely that the Child Guidance Clinic will become a permanent memorial to Adler's fame. After Adler came Jung, a deserter from Freud's school. The account of his principles, given in Chapter VII, leaves us far out at sea. The author refers to them as obscure. We find them unintelligible.

The final and most interesting chapter in the book is the only one that makes any scientific appeal. It deals with the great researches of Pavlov and the machinery of the mind. The discovery of conditioned reflexes, an extension of the view first put forward by Herbert Spencer, that instincts are nothing but complicated reflexes.

The salivation of a hungry dog when shown food was regarded by Pavlov as a purely mechanical matter—like pulling its foot away from a hot iron, and he proceeded "to investigate the characters of this reflex as though it was a simple spinal cord reflex and not a complex *psychical* one." (The italics are ours.) It seems to us a pity to introduce psychology here. Surely, having secured the problem in a physical and measurable environment, solution is in sight and has no use for subjective surmises or anthropomorphic attitudes.

This book has given us great pleasure and instruction, and should be valuable to medical men who have the time and interest for psychological questions.

The addition of an index would be much help to the reader.

P. J.

An Introduction to Comparative Biochemistry. By ERNEST BALDWIN, B.A., Ph.D. With a foreword by PROFESSOR SIR FREDERICK GOWLAND HOPKINS, F.R.S. [Pp. xviii + 112, with 11 figures.] (Cambridge: at the University Press, 1937. 5s. net.)

BIOCHEMISTRY, though a comparatively young science, is growing very rapidly and extending its investigations into so many different fields that it is calling for more and more specialisation on the part of its workers. This being so, it is becoming increasingly difficult to keep abreast of the whole subject, and a book such as the one under review should therefore find a ready welcome among students of biochemistry. The author states in the introduction that "the task of the biochemist is, after all, the study of the physicochemical processes associated with the manifestations of what we call life. . . . From this point of view a starfish or an earthworm, neither of which has any clinical or economic importance *per se*, is as important as any other living organism. . . ." This quotation may be taken to represent most admirably the outlook of the book, and the citation of the titles of a few of the subjects dealt with will show how the author has elaborated this :—The Colonisation of Fresh Water ; The Ionic Composition

of the Blood ; The Regulation of Osmotic Pressure ; The Colonisation of Dry Land ; The Conservation of Water ; The Excretion of Nitrogen ; The Distribution of Nitrogenous Bases ; Respiration ; Respiratory Catalysts ; Animal Luminescence ; etc.

One of the aims of the book, according to the Preface, is to provide a starting-point for those who may find themselves attracted to the subject. The story told by the author is unfolded in so interesting a manner that he may rest assured that his writing will attract many to the subject who might otherwise remain in ignorance. Two quotations from Tho. Spratt's *The History of the Royal Society*, 1922, are singularly well chosen and provide a most appropriate and quaintly humorous setting to an altogether excellent little book.

P. H.

The Essentials of Chemical Physiology. By the late W. D. HALLIBURTON, M.D., LL.D., F.R.S., J. A. HEWITT, Ph.D., D.Sc., and W. ROBSON, Ph.D., D.Sc. Thirteenth edition. [Pp. xii + 350, with 56 figures, including 1 coloured plate.] (London, New York, Toronto : Longmans, Green & Co., 1936. 9s.)

HALLIBURTON produced his text-book of Chemical Physiology forty-four years ago, and new editions have been called for at approximately three-yearly intervals ever since. In preparing the twelfth edition Halliburton had the assistance of Hewitt and Robson, who, now that Halliburton has left us, have taken on in full the task of preparing the thirteenth edition. A considerable re-arrangement has been made ; certain matters of pure organic chemistry have been deleted, and a few experiments of a character more advanced than is usually necessary for the medical student have also gone : moreover, the distinction between an "elementary" and an "advanced" section has been dropped. But the almost unique character of the book—the successful combination of "theory" and "practical work"—is unaffected. Although pure organic chemistry is removed, the Editors have wisely retained, and even expanded, the chapter on physical chemistry in its applications to Physiology ; the treatment of this topic is delayed, however, until the properties of fats, carbohydrates and proteins have been dealt with, and the nature and analysis of food (Chapters 1–4). Urine is now dealt with in one chapter only, but without any condensation from the five chapters in the last edition.

The treatment of muscle chemistry in the twelfth edition left something to be desired, but in the present volume this shortcoming has been attended to. The suggestion that the de-amination of adenylic acid is a reversible reaction does not, however, represent a widely accepted view. Another departure from current practice is the distinction drawn between the partial pressure of a gas in the atmosphere above a solution, and the "tension" of that gas dissolved in the solution. The two are said to be equal at equilibrium. "Tension" defined in this way seems indistinguishable from the osmotic pressure which the solution may legitimately be supposed to possess in virtue of the presence of the dissolved gas. It is therefore arguable that the term "tension" is superfluous.

Each section of the book has evidently been thoroughly scrutinised since the last edition, and a number of discoveries and methods brought out since 1932 have been incorporated. The index has been further enlarged, and

contains six references per page of text : a useful proportion in a book of this kind.

The authors are to be congratulated on the skill with which they have preserved the virtues of Halliburton's work while removing those few shortcomings which were mainly the inescapable result of the march of time.

P. EGGLETON.

Accidents and Their Prevention. By H. M. VERNON, M.A., M.D.
[Pp. x + 336, with 61 figures.] Cambridge : at the University Press, 1936. 15s. net.)

THIS book is not a medical text-book, but a summary of existing knowledge which will prove useful to a wide circle of medical and non-medical readers. The sources from which Dr. Vernon has drawn his material are many. To his own knowledge and experience he adds information derived from the investigations carried out by the Home Office, the Industrial Health Research Board, the Ministry of Transport, the National Institute of Industrial Psychology, the National Safety First Association, etc. The first four chapters serve to state the "Accident Problem." The influence of personal susceptibility and of "environmental conditions" are examined. Chapters V-VII deal with "Road Accidents and their Prevention"; the relative importance of such factors as speed, driving tests and alcohol, etc., are discussed. The author then deals with Railway Accidents and Accidents in the Home. Three chapters follow dealing, in some detail, with the causes and prevention of Industrial Accidents, and one chapter is devoted to Coal Mining Accidents. The study is completed by a summary of conclusions and by an adequate index. The author's main conclusion is that a reduction in the numbers of accidents is more likely to result from psychological methods of investigation and of prevention than either from an extension of legal control or from the further development of mechanical safeguarding. Such a conclusion will be generally endorsed.

The author may be congratulated upon this book, which should be a useful one to all who are concerned with the problems of Accidents in Modern Life.

H. E. C.

HISTORY OF SCIENCE

Matthew Boulton. By H. W. DICKINSON. [Pp. xiv + 218, with 15 plates and 6 figures.] (Cambridge : at the University Press, 1937. 10s. 6d. net.)

THE study of Britain's industrial awakening in the eighteenth and nineteenth centuries has been considerably enriched by the several books written on the lives of the early engineers, James Watt, Richard Trevithick and now, Matthew Boulton, by Mr. Dickinson.

Though not the romantic figure of Trevithick, Boulton was in certain senses equally a pioneer with Watt, and, without his optimism and business acumen, it is doubtful if Watt's pessimism would not have foredoomed his inventive genius to failure. Boulton's life falls broadly into four divisions, a hardware manufacturer, in the language of those times a toymaker; a producer of artistic Sheffield and silver plate, ormolu and mechanical pictures; the development of Watt's steam engine; and the improvement of coinage.

His story, delightfully related, tells of his contacts with John Roebuck, Benjamin Franklin and William Murdock, who applied for a position in a wooden hat of his own turning. His friendships with Erasmus Darwin, Josiah Wedgwood, Dr. Priestley and Sir Joseph Banks, President of the Royal Society, of which both Boulton and Watt were elected Fellows in 1784, all find their place in this enlightening study.

Matthew Boulton delighted to point out that he was born in 1728, the same number as that of cubic inches in a cubic foot, and this outlook was a key to his whole character. He is instinctively thought of in connection with the development of the steam engine, but in reality there were other claims to fame equally his own. He was one of the first to realise the principles of machine industry, to press for standardisation of output with its reduction of cost but without any decrease of quality, whilst he rated highly the value to industry of first-rate artistic designs—examples of his candelabra and other products still extant bear witness to this. An admirable employer, one reads of his boys at the coining presses being clothed in white trousers and jackets which were washed every week; in short, his interest in employee welfare was as keen as his business sense. The debt the country owes Boulton for placing its copper coinage on a satisfactory basis is too often overlooked: between 1797 and 1808 no less than 3531 tons of copper coin was minted at Soho.

This book with its well-designed Preface and complete Index will repay study by all interested in the lives of the early engineers, and there must be few not interested in that evolutionary period.

C. E. R. S.

Portraits of Eminent Mathematicians, with brief biographical sketches. By DAVID EUGENE SMITH. Pictorial Mathematics, Portfolio No. 1. [Pp. 52.] (New York: Scripta Mathematica, 1936.)

THIS is a portfolio containing a set of portraits of twelve famous mathematicians: Archimedes, Copernicus, Viète, Galileo, Napier, Descartes, Newton, Leibniz, Lagrange, Gauss, Lobachevsky, Sylvester. The portraits are in every case reproductions of originals taken from life, "no fanciful picture being used," we are told in the introduction. In one case, that of Archimedes, this was obviously difficult; the Roman mosaic of A.D. 70 could hardly give more than a traditional likeness, but it was clearly the nearest approach that could be found.

To each picture are annexed a couple of pages giving a brief account of the biography of its subject. But it seems a pity that no reference indicating the origin of the picture reproduced, with particulars of the artist, date and present location, has been included. This omission is particularly to be regretted in those cases (*e.g.* that of Newton) where a number of such portraits are known to be in existence.

The biographical notes are obviously intended for the non-mathematical reader. The relative stress laid on different achievements and events is occasionally rather surprising, as when a whole paragraph is devoted to Galileo's "geometric" compasses, but his work on the strength of materials is not mentioned, and the tragedy of his persecution is dismissed in the statement that "he was in conflict with the Inquisition, and as a result was not looked upon with favour by the ecclesiastical authorities."

The selection of the favoured twelve would not be easy to justify, if it were meant to be final. Few would agree to include Leibniz and exclude Euler,

or to place Lobachevsky above Cauchy or Abel. This criticism is met, however, by the hint given in the introduction that this portfolio is a first instalment, not an ultimate choice.

A very valuable feature is that, wherever possible, a facsimile of the handwriting has been added to the notes and the portrait in each case.

The reproductions are excellent and the whole portfolio is attractively produced.

L. N. G. F.

The Development of Modern Medicine. By RICHARD H. SHRYOCK.
[Pp. xvi + 442, with 8 plates and 10 charts.] (Philadelphia: University of Pennsylvania Press; London: Humphrey Milford, 1936. 18s. net.)

THE relation of modern medicine to social history is a fascinating aspect in the study of human progress. Emerging shyly from the medieval mysticism of the sixteenth century together with the awakening of the physical sciences, medicine remained handicapped by the poverty of its data, by the superstitions and prejudices of the laity, by the opposition of the priests, and by the conservatism of the medicals themselves, at that time distracted by their philosophies and metaphysics and their enforced limitation to the qualitative view of their science; measurements and quantitative estimations were not then applicable or possible, so that the treatment of disease was purely empirical and still often regarded as impious. The author catalogues a long series of names handed down to us from this period showing an oscillating progress from generation to generation, slight advances followed by setbacks, and he shows very clearly that only by the introduction of measurement and mathematical treatment of data did medicine become more a science and less an art. Especially during the last century was progress extraordinarily accelerated by the addition of facts resulting from improved anatomical and physiological study and the development of microscopy and staining methods which enabled histology, bacteriology and immunology to explain the pathology and etiology of disease and place medical science on a firm foundation which led to prophylaxis and initiated the era of the science of health.

This is a widespread subject and the author has omitted few of the branches of medicine from his story. The chapter dealing with public health seems to be more intimately in touch with the original sociological thesis and is also more continuously written and is more easily read than some of the other chapters which suffer from the author's amazing labour in collecting authorities, and often from confusing chronology.

The accompanying illustrations have no immediate reference to the text and have already served in previous publications and they show a meretricious realism which appears rather out of place.

Dr. Shryock has produced a most interesting book which should appeal alike to professional and to lay readers.

P. J.

The March of Science: A First Quinquennial Review, 1931-1935.
By various Authors. Issued under the authority of the Council of the British Association for the Advancement of Science. [Pp. viii + 216.] (London: Sir Isaac Pitman & Sons, Ltd., 1937. 3s. 6d. net.)

As stated in the Preface the Council of the British Association in issuing this Review had a twofold object in view, namely, to bring the progress of

the sciences before (a) the layman—thus fulfilling one of the Association's prescribed objects, and (b) the scientific worker in one branch who may wish for information concerning advances in branches of knowledge other than his own. There are in all 16 sections each dealing with a different subject and written by an expert in that subject. Beginning with an article on Cosmical Physics by Sir James Jeans, there follow sections on Geology, Geography, Botany, Zoology, Anthropology, Psychology, Educational Science, Economic Science, Agricultural Science, Physiology, Biochemistry, Physics, Physical Chemistry, Organic Chemistry and Science and Industry. This is a goodly list and covers most fields, except medicine and surgery which were not found to lend themselves to treatment on the general lines of this review. This is a book which can be opened anywhere and read with profit and interest; the reviews are naturally very condensed but nevertheless they contain a great wealth of information in sufficient outline to indicate the general trend of the advances and to whet the appetite for more detail. Though not a large book, the price is very reasonable for the amount of information and instruction which it provides. It would be invidious to single out any one section for special comment and quite impossible to convey any more particulars as to the nature of the contents of this very useful book, but it may be safely recommended as a mine of information in a small compass.

P. H.

MISCELLANEOUS

The World of Science. By F. SHERWOOD TAYLOR, Ph.D., M.A., B.Sc. [Pp. xvi + 1064, with 48 plates and 533 figures.] (London: William Heinemann, Ltd., 1936. 8s. 6d. net.)

THIS book is not merely the most recent and best attempt "to answer in simple terms the questions which the ordinary man and woman ask about living creatures, the world and the mechanical devices daily encountered by all." It is much more a personal triumph for Dr. Sherwood Taylor and an achievement which must serve to rank him with those select few who like Andrade, Bragg, Huxley and Jeans possess the greatly to be envied gift of popular exposition.

Since there are over a thousand pages of text, scarcely one without some special merit, whether in its happy choice of subject matter or felicity of treatment, over five hundred fine diagrams and sketches, and fifty pages of wholly admirable photographs, it is difficult to select any representative extracts. The keynote of the book is modernity of treatment and subject matter, an acid, for example, being described as a substance from which hydrogen "is in some measure detached as a hydroxonium ion" on solution in water. The description and diagrammatic representation of the formation of salt crystals from solutions of caustic soda and hydrochloric acid (p. 579) is but one topic described better in this book than in many actual text-books of science.

However, like Browning's Grammarian—"this high one aiming at a million misses an unit"—Dr. Sherwood Taylor occasionally lapses from infallibility. Thus, in his description of the rusting of iron, the impression might be gained that hydrogen gas is liberated in amount proportional to the weight of iron rusted. The description of the lead accumulator (p. 299) states that, when discharged, the plates are coated with pure lead and lead sulphate

respectively. Wisely, perhaps, the subject of valency has been glossed over: yet in the many structural formulæ, the apparent inconsistencies in, for example, linking two oxygen atoms sometimes by two bonds (pp. 647, 674), and sometimes by one only (pp. 615, 623, &c), will probably puzzle the careful reader.

Yet such points as these scarcely detract from the merits of the book as an organic whole, though their correction will certainly enhance the value of future editions—for there will surely be many such demanded.

This is indeed a book to buy and to read, as the reviewer has done, with profit and real pleasure.

H. I.

The Scientific Journal of the Royal College of Science. Vol. VII.

Containing papers read during the Session 1936-37 before The Imperial College Chemical Society, The Royal College of Science Natural History Society and The Royal College of Science Mathematical and Physical Society. [Pp. 146, with figures.] (London: Edward Arnold & Co., 1937. 7s. 6d.)

THIS volume contains eleven out of a total of forty-three papers delivered before the three societies mentioned; they are intended to represent the latest trend of scientific thought in the particular fields they deal with. The papers here selected for publication, though not of equal interest to all readers, offer a fairly wide selection of subjects. Among those of outstanding merit may be mentioned one by Professor Finch on "The Structure of Polish," which gives an account of the light thrown on the nature of polished surfaces by an examination of the electron diffraction patterns which they produce; an important practical application of the results obtained is the increased resistance to wear and tear of aluminium surfaces which may be achieved by burnishing with a magnesium rod as the result of the formation of a superficial layer of spinel. A very interesting and complete account of the Natural Coumarins and their effect on fish is contributed by Dr. N. Platzer. Other papers deal with "Some Aspects of Clay Chemistry," "Plant Poisons," "The Habits of the Solitary Wasps," "Virus Diseases in Strawberries," "The Development of the Photographic Lens," "Applications of the Thyatron," and "The Photographic Latent Image."

The whole collection produced as it is entirely under student control is a very creditable piece of work.

P. H.

The Wandering Spirit. By RAGNAR NUMELIN, Ph.D. With a Foreword by Dr. E. WESTERMARK. [Pp. xvi + 375.] (London: Macmillan & Co., Ltd., 1937. 20s. net.)

IT is one of the leading characteristics of our race that it has distributed itself in most latitudes under equatorial as well as arctic climes. This prime indication of its capacity for wandering leads the student to hope that the author will bring a wide knowledge of archæology and anthropology, including ethnology, to bear upon this fact, to trace some of the main drifts through which man distributed himself over the globe and to draw conclusions thence. But *The Wandering Spirit* eschews this great task and after a few very thin references to early movements it proceeds to work out its chosen aim of collecting literary references to mobility of peoples. The author's attitude is illustrated by his statement that what Cæsar and Tacitus wrote

about the nomadism of the ancient Teutons must be considered as having greater weight than modern speculations. One is disposed to agree, emphasising the word *speculations*, for these are indeed a curse of modern thought in Germany, but, surely, before expressing an opinion, Dr. Numelin should have learned something about Central European archaeology. None of the leading modern surveys by Childe or Kraft or Wahle is mentioned. Again, one of the most fascinating topics relating to Britain and the Danish region is the fact that at the dawn of civilisation in both a drift that had come through Central Europe met people who had come by sea from the Mediterranean. Motives and results of these movements are of great importance even for the understanding of modern Europe. Dr. Numelin, however, confines his attention more especially to the movements that seem relatively aimless and his interest is in the demonstration of the theory that a mere "wandering instinct" is not a sufficient explanation, though this instinct may grow with experience and become very potent indeed. The references and bibliography of this book are perhaps its chief value; we still need a book on the Wandering Spirit that shall interpret wanderings and consequent contacts, with due regard both to motives of wandering and to its effects which have contributed so much to cross-fertilisation of ideas. When that book is written one hopes its author will remember how dangerous it is to take one detail out of the life of a people and argue about it on the basis of analogy with another detail in the life of another people.

H. J. F.

Our Natural Resources and Their Conservation. Edited by A. E. PARKINS and J. R. WHITAKER. [Pp. xii + 650, with 130 figures.] (New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd., 1936. 25s. net.)

THIS is a symposium by twenty-two contributors, dealing with various natural resources and the problems associated with their rational use in U.S.A. Many of the authors are well known to English geographers, and the names, among others, of W. W. Atwood, O. E. Baker, J. Russell Smith, Ellsworth Huntington and Nels Bengtson should offer a guarantee of the value of the work. It is divided into ten parts, of which Parts II, III, IV, V and X receive about five-sixths of the space. Part II has eight chapters dealing with agriculture, including such topics as soils, soil erosion and the agricultural outlook. Part III has two chapters on the forests and their utilisation; Part IV four chapters on water supply, waterways, water power and floods; Part V two chapters on minerals, including mineral fuels, and Part X two chapters on local, state and national planning. Straightforwardly written, it is entirely suitable to the intelligent layman, and will prove of very great value to the student of the economic geography of the United States. The editors are to be congratulated both on their planning of the book and on their choice of contributors.

R. O. B.

The Preservation of our Scenery. By VAUGHAN CORNISH, D.Sc. [Pp. xiv + 91, with 12 illustrations.] (Cambridge: at the University Press, 1937. 7s. 6d. net.)

THIS book contains a reprint of 6 essays and addresses relating to the preservation of our scenery published between 1929 and 1936. The author

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divides scenery into 6 types—Coast, Mountain, Moor and Down, River Gorges, Woodland and Fenland, and advocates the formation of National Parks to illustrate these types, distributed as equitably as possible in relation to the chief industrial districts. He suggests the following districts as fulfilling the necessary conditions. For coast scenery, the cliff for 10 miles on either side of Lands End and also the Pembrokeshire coast between St. David's Head and St. Ann's Head. For mountain scenery, the centre of the Lake District within a circle of 12 miles radius centred on Dunmail Raise together with the Snowdon area containing a tract 28 miles by 14 miles. For moorland scenery, the Dartmoor Region and portions of the Pennine Chain and Northumberland: these areas would also include river scenery and under this heading Dovedale also, as having a special claim, together with the gorges of the Wye as proposed by Lord Bledisloe for the Forest of Dean national park. For fenland scenery, the author suggests a tract in the Broadlands traversed by the River Bure and its tributaries. In the later essays the author enters into further details. He stresses the value of trees in the English landscape and points out that the personality of the tree is related to the fact that it stands upright, as we do with trunk and limbs, and that human figures appearing in a woodland scene have a special charm which is lacking when they are viewed in the open country. Other points considered are the pictorial unity of architecture and nature in English scenery and the fact that types of good village architecture in England were laid down in Tudor times. He expresses the hope that the sentiment which protects ancient monuments may include the dignified architecture (collegiate buildings and cathedrals) which is a precious heritage from the eighteenth century.

The book is illustrated with twelve reproductions from sketches by the author, some of which are of considerable merit. The view of the Whin Sill on the Roman Wall is particularly happy and illustrates the characteristic texture of the Basalt admirably.

The book is of special value at the present time while public interest has been aroused in the necessity for immediate action to be taken for the preservation of definite areas by the establishment of National Parks.

E. J. G.

Exercises in Cartography. By FRANK DEBENHAM, O.B.E., M.A. [Pp. viii + 135, with 109 figures.] (London and Glasgow: Blackie & Son, Ltd., 1937. 8s. 6d. net.)

MAPS are the special implements of the geographer, and mapwork of all kinds is therefore the geographer's special job. In this book Prof. Debenham gives us in printed form, admirably set out and illustrated, the exercises set during a number of years to students in his department of Geography at Cambridge. They correspond broadly with the exercises worked by students in most geography departments of universities, and will therefore be widely welcomed and used. The chapter on map projections is very short, but the author no doubt takes it for granted that other well-known works will supplement his book here. He gives an attractive introduction on drawing instruments and materials as well as a critical review of styles of map-lettering which may be practised by amateurs or should be avoided by them. The instructions concerning relief models may occasion some difference of opinion; it is rarely, if ever, possible to make an effective model, even of a hill-area,

in Britain with horizontal and vertical scales both 1 inch = 1 mile ; 1 inch = 2000 feet vertical is often effective and on the whole avoids too much exaggeration.

H. J. F.

Naven : A Survey of the Problems suggested by a Composite Picture of the Culture of a New Guinea Tribe drawn from Three Points of View. By GREGORY BATESON, M.A. [Pp. x + 286, with 28 plates and 6 figures.] (Cambridge : at the University Press, 1936. 18s. net.)

THE Naven are ceremonies performed by the Iatmul people who live on the middle reaches of the Sepik River in the Mandated Territory of New Guinea. The book endeavours to describe a certain type of ceremonial behaviour of those people. During these ceremonies the men dress as women and women as men. The author tries in his own words "to relate this behaviour not only to the structure and pragmatic functioning of Iatmul culture, but also to its ethos." He is one of the most honest writers that a fairly wide reader of miscellaneous anthropological literature has had the good fortune to meet for some time. He frankly admits that he wasted a good deal of his time in New Guinea and that there are all sorts of gaps in his notes. He certainly has not produced the orthodox and proper account of an anthropological expedition which makes the hardened sceptic wonder how on earth the inexperienced searcher after truth found it all out. On the contrary, he positively revels in his gaps. The book is at once a statement of dissatisfaction with many existing methods and an attempt to suggest something new. The points which the author especially wishes to emphasise are first the "ethos" by which he means emotional aspects, and second the "eidos" by which he means cognitive aspects. As he is searching after truth and, it would appear, rather hampered than helped by such philosophical phraseology as he uses, the book is not easy to read. It is not fair to quote out of context but Mr. Bateson's use of such words as integration or "pragmatic" functioning (the quotation marks are his, not mine) is not easy to understand. On the other hand, his very difficulties and the frank way in which they are discussed are most instructive. The photographs are excellent and made the more valuable by the notes which accompany each. There is a good glossary, but a table of contents is hardly a sufficient substitute for an index.

L. H. D. B.

The Nation's Intelligence. By J. L. GRAY. Changing World Library, No. 1. [Pp. vi + 154, with 2 figures.] (London : Watts & Co., 1936. 2s. 6d. net.)

IN this little book the author has tried to present an account of the modern methods of the Intelligence test which is used so extensively to-day, and at the same time he discusses the question of the differences between the average intelligence of social groups. The book is intended primarily for consumption by the general "intelligent" public, and it should succeed in its object, which is to take us behind the scenes in the preparation of intelligence tests and to awake our consciences to the mass of "intelligence" in the nation waiting for a chance to demonstrate its existence.

Mr. Gray does not avoid the major issue of what information we get

when we have the results of intelligence tests on a group of persons. The old methods of judging a child's capacity for citizenship, for application in some occupation, for living generally, consisted of tests of handwriting, spelling, composition, arithmetic and testing memory by dates and geographical features. The newer intelligence tests try to guide us to a more fundamental truth than before. But they do not pretend to tell us which individual will make a fortune on the Stock Exchange, who will be successful as an Industrialist or Administrator or Crossword Puzzle Solver.

Mr. Gray points out that other things besides ability to benefit decide the choice which the nation makes of those persons of young age who are admitted to centres of higher learning, and who are therefore on the road to positions of influence in the nation's destiny. The economic advantages which belong to the higher social classes enable the children of those classes to greater educational benefits. Mr. Gray doubts if there is much, if any, greater ability, on the average, in this group of children when compared with children of other social groups. How far it is reasonable to take the results of intelligence tests only into account here it is difficult to say. There are all kinds of advantages which belong to certain social groups which influence those fortunate (or unfortunate) ones who belong there, which cannot be appraised numerically. Herein lies, perhaps, the difference between Education as Book-learning and Culture in its best sense.

But there is certainly a case for investigation. Anyone who has had dealings with "Delayed Higher Education," where one meets older people, keen, intelligent and active, who missed opportunities or who never had opportunities when young of getting to know things, realises what potentialities there are in the nation's youth.

E. C. RHODES.

Creative Education and the Future. By OLIVE A. WHEELER, D.Sc.
[Pp. xi + 365, with 8 figures.] (London: University of London Press, Ltd., 1936. 8s. 6d. net.)

THIS book aims at showing that there are two educational commandments to-day—to train human beings for the living present, and to pay more attention to their individual needs. Education will not, it argues, be "creative" until it is better adjusted to the varieties of individuals for whom provision has to be made. The book is written in a very clear style, is well printed and reads easily. The writer, possibly hoping that the "layman" will read the work, avoids a great many technical terms and puts her matter simply, though it is a pity that the phrase "psychologize education" has been adopted for the importance of studying individual needs.

In the first two sections of the book, "The Living Present" and "The Living Individual," the author has collected in concise form most of the expressed thoughts of the last century on education and its allied subjects, and has evidently kept herself well abreast of developments, and discussions of suggested developments in the educational world. She touches on or alludes to Women's Institutes, The Association for Citizenship, international jamborees, Universities in a changing world, the Gary Schools of America, as well as giving fuller consideration to new problems such as that of increased leisure. She considers that a "tendency to ordered change . . . is the outstanding feature of modern education" and regards it as a hopeful

sign. She courageously points out that "Education needs to be religious in its broadest sense," and to be effective in influencing modern life religion must be adventurous.

In the section on living individuals the writer states very clearly her conviction that the three stages of the growth of the human being are Infancy from birth to 5 years, Childhood from 5 to 11 or 12 years, and Adolescence from 11 or 12 to 21 years; and that in each of these stages there is first rapid growth followed by "filling out" both in the physical and mental development. She rebuts the divisions blessed "for convenience" by Professor Cyril Burt—0 to 7 years, 7 to 14 years, 14 to 21 years. She points out that the compilers of the Hadow Report and its successors bore the former divisions in mind, but she issues a sound warning that the principles underlying the reorganisation proposals must be understood and the new problems faced before there will be a real improvement in the *quality* of Education.

One naturally turns to the last section to find out what the "Trends of development in Modern Education" are or should be, but here one meets with a sense of disappointment. The author's able summarising continues; the need of nursery schools, the raising of the school-leaving age, the selection of the University student, whether education shall be a degree subject, are already much-debated matters, and she sums up the arguments well. But definite constructive contributions to solutions of educational problems are not many. The best are the following:

(a) The principle enunciated by Sanderson of Oundle that "we must not cast out our weak ones" must not be forgotten, but she urges that "we must do no violence to our strong ones," and children of high intellectual ability and special gifts must have special attention in order that their work and games may be sufficiently stimulating.

(b) The false antithesis between technical and "liberal" education should be broken down and each individual should receive, according to his gifts, a training for work and for leisure. (It is a fair comment that Universities "lag" in adjusting themselves to the living present.)

(c) Her scheme for the curriculum in the new senior schools is one of the best yet conceived and is worth much consideration. It caters for the physical needs of the scholars and is broad on the mental side, giving attention to the humanistic, the scientific and the artistic. It includes personal culture, and asks that vocational training shall be deferred to late in the course. It also includes moral and religious training.

The book is stimulating and deserves to be read.

F. M. W.

Books and Documents : Dating, Permanence and Preservation.

By JULIUS GRANT, Ph.D., M.Sc., F.I.C. [Pp. xii. + 218, with 36 figures, including 12 plates.] (London: Grafton & Co., 1937. 10s. 6d. net.)

THE purpose of this book, which is partly indicated by the sub-title, is fully explained in the Preface: it is, first, to help librarians, collectors, antiquaries and certain scientific workers "to know something of the age, history and origin of the materials" of the books and documents they handle, and to appreciate "the extent to which these materials are likely to resist the ravages of time, and the best way of assisting them to do so," and,

second, to interest and assist "all those concerned with the manufacture and production of books or documents."

The book is divided into two parts, as follows :

Part I: this includes the history of paper-making; the method of dating books and documents from the physical structure of the paper, the nature of the fibre and ink, the watermark, and the sizing, loading and colouring matters used. The methods of determining the various characteristics enumerated are then described, a special chapter being devoted to the examination by means of ultra-violet rays, which are called ultra-violet light, a common mistake, although the rays are not luminous.

Part II: this deals with the nature and cause of the deterioration of paper, ink and bindings, the methods of testing for permanence and the standards suggested.

The book is excellent and should prove most useful to those interested in such matters, especially to librarians, lawyers and specialists who may be called upon to deal with the subject of the date of questioned documents.

Naturally no book is, or can be, perfect, and by pointing out shortcomings and mistakes, the reviewer hopes that the inevitable future editions may be made still more useful. One marked defect is the very poor illustrations (Figs. 9 to 21) showing the structural characteristics of the various paper-making fibres, which, strangely, do not include one of the most important fibres used, namely linen. The illustrations of dissecting-needles for the examination of paper, a bottle for the staining solution for use in the identification of fibres, the one paper-testing machine given and the projector for film-slides, all seem unnecessary and the last two are very poorly reproduced. With reference to papyrus, it is stated that this material "is the laminated bark of an Egyptian river plant, the constituent films of which were pasted together crosswise, with gum or starch, to form a hard sheet." Papyrus was not the bark of the papyrus plant, but the pith; the separate layers were not films, but, until beaten, thick slices, and these layers were not pasted together with either gum or starch, the adhesive being the natural juice of the plant, an extraneous adhesive being employed only to fasten together the short pieces, as made, in order to produce a long roll.

The book is well printed and bound and contains a good bibliography and index; it is strongly recommended.

A. LUCAS.

The Subject Index to Periodicals, 1936. [Pp. xii + 598 columns.]
(London: The Library Association, 1937. £3 10s. net.)

To many scientists the elaboration of method employed in bibliographical works is often a cause of much irritation. Classification systems with minute subdivisions of the subject are not always well adapted to the needs of those who are occupied with problems of research and the use of complicated symbols bearing no plain meaning is apt to make them blind to the true merits of work to which much careful labour has been devoted. On such grounds as these there can be no complaint against the Library Association's Subject Index; it employs a simple alphabetical arrangement of headings with no subdivisions, avoids all decimal and other symbolic devices, and provides a complete list of titles of journals to which reference is quite simple in all cases in which the abbreviated titles are not at once intelligible. But

the scientist must remember that the Index is compiled for the use of enquirers generally and does not profess to cater for the specialist, and that the headings adopted are therefore those under which the layman may be expected to seek information on a given topic.

It is perhaps as well to repeat the reminder which has appeared in these pages on previous occasions when a volume of the Subject Index has been reviewed, to the effect that the Library Association intentionally abstains from indexing those journals which are already adequately covered by the recognised indexes of a specialist nature such as Index Medicus and Engineering Abstracts. This is a perfectly justifiable course to take and is far from being any reflection upon the admirable work done by Mr. T. R. Powel, the Library Association's general editor, and his corps of voluntary assistants.

J. W.

BOOKS RECEIVED

(Publishers are requested to notify prices.)

- Projective Geometry.** By Boyd Crumrine Patterson, Ph.D., Professor of Mathematics, Hamilton College. New York : John Wiley & Sons, Inc. ; London : Chapman & Hall, Ltd., 1937. (Pp. xiv + 276, with 113 figures.) 17s. 6d. net.
- Plane Trigonometry. With Five-Place Tables.** By Harvey Alexander Simmons, Ph.D., Associate Professor of Mathematics, North-western University, and Greenville D. Gore, Ph.D., Professor of Mathematics and Chairman of the Departments of Mathematics and Engineering Drawing, Central Y.M.C.A. College of Chicago. New York : John Wiley & Sons, Inc. ; London : Chapman & Hall, Ltd., 1937. (Pp. viii + 81, with 122 figures and 6 tables.) 10s. net.
- Fluid Mechanics.** By Russell A. Dodge, Associate Professor of Engineering Mechanics, and Milton J. Thompson, Assistant Professor of Aeronautical Engineering, University of Michigan. New York and London : McGraw-Hill Publishing Co., Ltd., 1937. (Pp. xii + 495, with 267 figures and 12 tables.) 24s. net.
- Applied Fluid Mechanics.** By Murrough P. O'Brien, Professor of Mechanical Engineering, University of California, and George H. Hickox, Hydraulic Engineer, Tennessee Valley Authority. New York and London : McGraw-Hill Publishing Co., Ltd., 1937. (Pp. xiv + 360, with frontispiece, 166 figures and 19 tables.) 21s. net.
- Storage Reservoirs.** By George Bransby Williams, M.Inst.C.E. London : Chapman & Hall, Ltd., 1937. (Pp. x + 293, with 168 figures, including 24 plates, and 15 tables.) 25s. net.
- Engineering Mechanics : Statics.** By S. Timoshenko, Professor of Theoretical and Applied Mechanics, Stanford University, and D. H. Young, Assistant Professor of Engineering Mechanics, University of Michigan. New York and London : McGraw-Hill Publishing Co., Ltd., 1937. (Pp. xiv + 334, with 464 figures.) 15s. net.
- Principles of Quantum Mechanics.** By Alfred Landé, Professor of Physics in the Ohio State University. Cambridge : at the University Press, 1937. (Pp. xii + 119, with 15 figures.) 7s. 6d. net.
- Properties of Matter.** By D. N. Shorthose, M.A., Physics Master, the City of Leeds School. London : William Heinemann, Ltd., 1937. (Pp. viii + 168, with 88 figures.) 4s.
- Elasticity, Plasticity and Structure of Matter.** By Dr. R. Houwink, Plastics Department, N. V. Philips Gloeilampenfabrieken, Eindhoven. With a

- Chapter on the Plasticity of Crystals, by Dr. W. G. Burgers. Cambridge : at the University Press, 1937. (Pp. xviii + 376, with 214 figures, including 7 plates, and 40 tables.) 21s. net.
- College Physics. By John A. Eldridge, Professor of Physics, University of Iowa. New York : John Wiley & Sons, Inc.; London : Chapman & Hall, Ltd., 1937. (Pp. x + 616, with 426 figures and 49 tables.) 18s. 6d. net.
- Electricity and Magnetism for Degree Students. By Sydney G. Starling, B.Sc., A.R.C.Sc., F.Inst.P. Sixth edition. London, New York, Toronto : Longmans, Green & Co., 1937. (Pp. viii + 630, with 449 figures.) 12s. 6d. net.
- An Outline of Atomic Physics. By Members of the Physics Staff of the University of Pittsburgh. Second edition. New York : John Wiley & Sons, Inc.; London : Chapman & Hall, Ltd., 1937. (Pp. x + 414, with 213 figures and 21 tables.) 18s. 6d. net.
- Molecular Beams. By R. G. J. Fraser, Ph.D., Imperial Chemical Industries Ltd. Methuen's Monographs on Physical Subjects. London : Methuen & Co., Ltd., 1937. (Pp. x + 70, with frontispiece, 22 figures and 7 tables.) 2s. 6d. net.
- Measurement of Radiant Energy. Edited by W. E. Forsythe, Incandescent Lamp Department, General Electric Company. New York and London : McGraw-Hill Publishing Co., Ltd., 1937. (Pp. xiv + 452, with 224 figures and 33 tables.) 30s. net.
- Fundamentals of Vacuum Tubes. By Austin V. Eastman, M.S., Assistant Professor of Electrical Engineering, University of Washington. New York and London : McGraw-Hill Publishing Co., Ltd., 1937. (Pp. xvi + 438, with 363 figures and 19 tables.) 24s. net.
- Electrolytic Condensers. Their Properties, Design and Practical Uses. By Philip R. Coursey, B.Sc., M.I.E.E., F.Inst.P., Technical Director, Dubilier Condenser Co. Ltd., London. London : Chapman & Hall, Ltd., 1937. (Pp. viii + 172, with 112 figures, including 10 plates.) 10s. 6d. net.
- Fundamentals of Engineering Electronics. By William G. Dow, Assistant Professor of Electrical Engineering, University of Michigan. New York : John Wiley & Sons, Inc.; London : Chapman & Hall, Ltd., 1937. (Pp. xiv + 604, with 207 figures and 17 tables.) 25s. net.
- Alternating Current Measurements at Audio and Radio Frequencies. By David Owen, B.A., D.Sc., F.Inst.P., Head of the Department of Physics and Mathematics, Sir John Cass Technical Institute, London. Methuen's Monographs on Physical Subjects. London : Methuen & Co., Ltd., 1937. (Pp. viii + 120, with 80 figures.) 3s. 6d. net.
- Aeroplanes and Aero Engines. By Captain P. H. Sumner, late R.A.F. Second edition. London : The Technical Press, Ltd., 1937. (Pp. xvi + 254, with 211 figures.) 15s. net.
- Noise. By A. H. Davis, D.Sc., Principal Scientific Officer in the Physics Department of the National Physical Laboratory. Changing World Library No. 6. London : C. A. Watts & Co., Ltd., 1937. (Pp. x + 148, with 20 figures, including 4 plates, and 5 tables.) 2s. 6d. net.

- Refrigeration Engineering. By H. J. Macintire, Professor of Refrigeration in the University of Illinois. New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd., 1937. (Pp. vi + 415, with 136 figures, including 7 folding plates, and 78 tables.) 22s. 6d. net.
- A Text-Book of Inorganic Chemistry for University Students. By J. R. Partington, M.B.E., D.Sc., Professor of Chemistry in the University of London, Queen Mary College. Fifth edition. London: Macmillan & Co., Ltd., 1937. (Pp. viii + 1062, with 390 figures.) 15s.
- Thorpe's Dictionary of Applied Chemistry. Vol. I (A-Bi). By Jocelyn Field Thorpe, C.B.E., D.Sc., F.R.S., F.I.C., Professor of Organic Chemistry and Director of Organic Laboratories, and M. A. Whiteley, O.B.E., D.Sc., F.I.C., lately Assistant Professor of Organic Chemistry, Imperial College of Science and Technology. Assisted by eminent contributors. Fourth edition. London, New York, Toronto: Longmans, Green & Co., 1937. (Pp. xxviii + 703, with illustrations.) 63s. net.
- Reagent Chemicals and Standards. With Methods of Assaying and Testing them; also the Preparation and Standardisation of Volumetric Solutions and Extensive Tables of Equivalents. By Joseph Rosin, Chief Chemist and Chemical Director, Merck & Co., Inc. New York: D. van Nostrand Co., Inc.; London: Chapman & Hall, Ltd., 1937. (Pp. x + 530.) 30s. net.
- The Reactions of Pure Hydrocarbons. By Gustav Egloff, Director of Research, Universal Oil Products Company, Chicago. American Chemical Society Monograph Series. New York: Reinhold Publishing Corporation; London: Chapman & Hall, Ltd., 1937. (Pp. xviii + 897, with 42 figures and 384 tables.) 84s. net.
- The Analytical Chemistry of Tantalum and Niobium. The Analysis of their Minerals and the Application of Tannin in Gravimetric Analysis. By W. R. Schoeller, Ph.D., F.I.C., late Lecturer in Mineralogy at the Sir John Cass Technical Institute. With a Foreword by G. Roche Lynch, O.B.E., M.B., B.Sc., D.P.H., F.I.C. London: Chapman & Hall, Ltd., 1937. (Pp. xvi + 198.) 21s. net.
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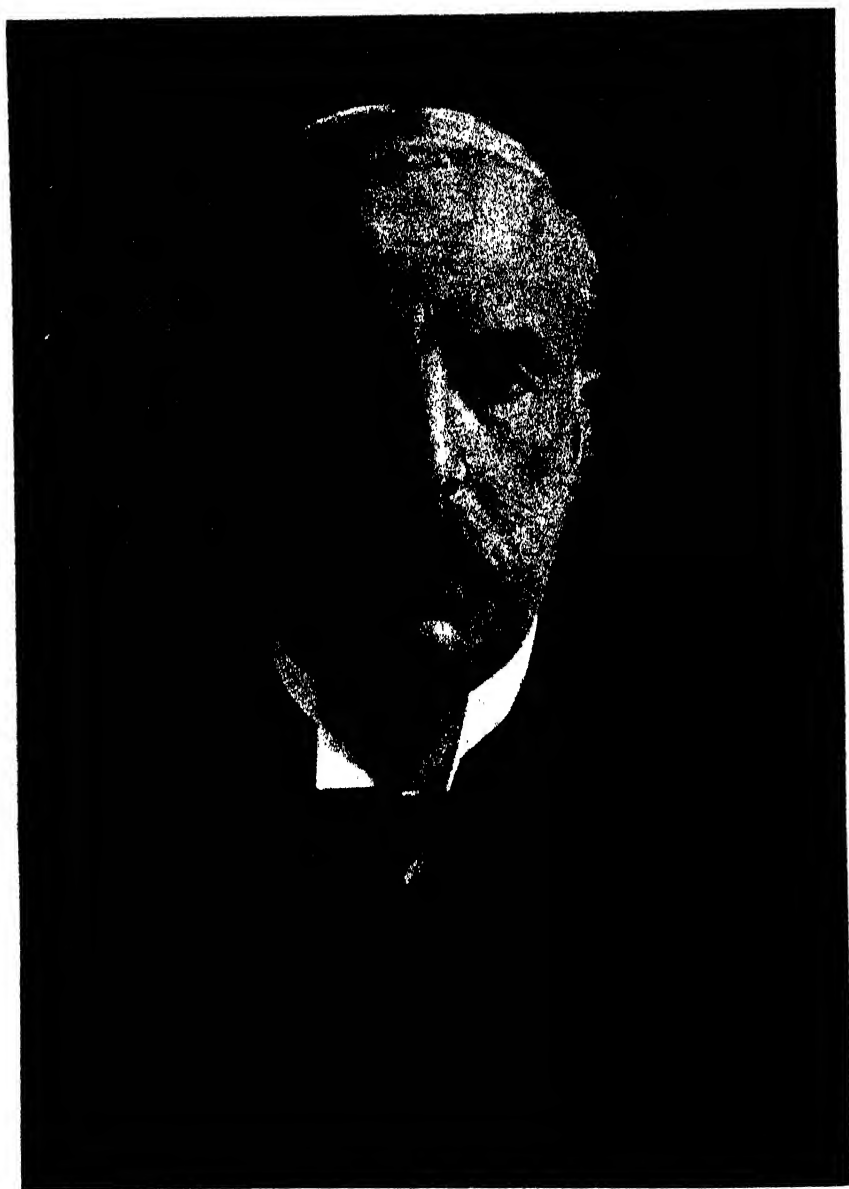
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LORD RUTHERFORD, O.M., F.R.S.

SCIENCE PROGRESS

LORD RUTHERFORD

THE news of Rutherford's death fell on us with such suddenness that it was not until some days after that we came to realise how great was the loss to science, and in particular to English science. Our feelings for the man himself were strongest in our minds during the days between the first bad news and the Abbey service, days when everyone who had known him was labouring under a very real distress. We were trying to realise that we would no longer hear his excited account of new ideas to be put to the test, his jests about old days and present personalities, or that word of approval so freely given and so long treasured. Everybody knew, of course, that the greatest experimenter of our generation had gone from among us, but it is now, when we put aside for a moment personal feelings and look round at the scientific scene, that we fully realise how great is the gap left.

The story of Rutherford's life and achievements has been often told during the past weeks: how in 1895 he came from New Zealand as a young man of twenty-four with an 1851 Exhibitions Scholarship, and entered the Cavendish Laboratory as the first "research student": how three years later, having already made a name for himself in Cambridge, he went to McGill University, in Toronto, where he carried out his first researches in radioactivity, and, with Soddy, put forward the theory of radioactivity: how, already world famous at thirty-six, he came to Manchester and there built up a school of research which attracted students from all over the world, and made the science of radioactivity the focus of scientific discovery: how in 1919 he succeeded his old teacher, Sir J. J. Thomson, as Cavendish Professor at Cambridge, and, with his students, carried out work on the atomic nucleus which was responsible for great schools of research on both sides of the Atlantic. He was stricken down at the height of his powers, and with a merciful suddenness, for a long illness would have been a terrible thing to a man of his ebullient temperament.

At Manchester Rutherford could devote practically his whole energies to research—not that he neglected his teaching duties, which he always took very seriously, but that the outside world made little claim on him. His powers of organisation were directed to planning his campaigns for advances into the unknown, in which every man in his little army was allotted a task suited to his competence. In those days he was working in the laboratory as an experimenter with his own hands, and wonderful hands they were. He knew by instinct just how hard he could hit a delicate piece of apparatus if he wanted to shift a pellet of mercury, just as he knew the limits to which rough apparatus could be made to go with proper care. He seemed to know by instinct what experimental difficulties were to be met, and how they could be overcome. His intuition for what was significant and what insignificant was extraordinary—after all, the whole theory of the nuclear atom arose from the fact that Rutherford realised that the few extra alpha particles scattered through large angles were profoundly significant. They could so easily have been passed over as a minor discrepancy.

The War first took him away from the laboratory into the fields, where his advice on practical matters, so often demanded in later years, was invaluable. It was about this time that he first became connected with the Department of Scientific and Industrial Research, in which he was later Chairman of the Advisory Council. It is not always realised how wide was Rutherford's interest during the post-War years in the relation between science and industry, and how much time he gave to scientific questions of immediate national importance—immediate, because indirectly Rutherford's researches in pure science were of profound national importance.

As Cavendish Professor he showed not only the full force of his scientific genius, but also his great powers of organisation. When he took charge of the Laboratory, it was suffering from the effects of the war years, and the equipment, though such magnificent work had been done with it by J. J. Thomson and his students, was comparatively primitive. He had to build up round him the great experimental resources needed for modern work, and to find the men who could control them. Further, he had to furnish inspiration for a very numerous body of enthusiastic students, of varied ability.

Into these different tasks he threw himself with characteristic energy and enthusiasm. His first work at Cambridge on artificial transmutation was carried out with his old technique of alpha particles and scintillations, but he had long been revolving in his mind the question of producing artificially accelerated atoms of sufficient energy to affect transmutations, and in due course in-

stalled apparatus to produce such particles, and urged Cockroft and Walton to try the effects of potentials which theory at the time held to be far too small, with results which initiated a new type of research. The neutron, discovered by Chadwick, had been envisaged as a possible entity by Rutherford, years before its experimental realisation. It was Rutherford's convictions and driving force that vitalised the Laboratory, and that drew around him the brilliant men who formed the backbone of the research school. His work at the Cavendish, however, gigantic as it was, represented only a part of his activities. He was full of encouragement for workers, however humble, in other fields : his genial presence at scientific gatherings always scattered seeds that bore good fruit : his lectures at the Royal Institution were characterised by brilliant anticipations and daring experiments : the book which he wrote with Chadwick and Ellis was a worthy successor to the famous *Radioactive Substances* of 1913.

His great plans for the Cavendish were, alas, never completed. During the last year or two he saw himself with sufficient funds at his disposal to realise his plans for a great modern laboratory, but he was snatched away before they could be completed, and it remains to be seen if he has left on record any sufficient description of what was his full scheme for the organisation, direction and division of the work. He has left things in a state of transition, outlined but unfinished. Whatever, and however brilliant, the future of the Cavendish Laboratory may be, it seems unlikely that it can ever again have that intimate and family aspect which it presented under the paternal direction of the great master whose passing we now salute.

E. N. DA C. ANDRADE.

THE STORY OF THE MAIDENHAIR TREE

By SIR ALBERT C. SEWARD, Sc.D., F.R.S.

INTRODUCTORY

IN March, 1936, several letters were published in *The Times* drawing attention to the remarkable history of the Maidenhair tree (*Ginkgo biloba* L.) and its unique position as a link between the present age and an almost incredibly remote past. The interest awakened by the correspondence suggested to me the possibility that a fuller account of the history, both of the Maidenhair tree itself and the family or group of which it is the sole survivor, might be acceptable to readers of SCIENCE PROGRESS. *Ginkgo* was selected as one of several examples of living plants of ancient lineage in a book first published in 1911 entitled *Links with the Past in the Plant World* and further reference was made to it in an article contributed to this journal in October 1935 on "Selections from the study of Plant Migrations revealed by Fossils." More recently, in an article published in *Nature* (May 1, 1937) attention was called to some important contributions to the geological history of the *Ginkgo* family by Dr. Florin of Stockholm and Professor Harris of Reading. My present aim is to give a fuller account of the story of *Ginkgo* and its allies, a story founded on data collected from plant-bearing rocks of many ages and from widely scattered regions. Evidence furnished by fossils enables us to state with confidence that the *Ginkgo* group of trees—the Ginkgoales—was once almost world-wide in its distribution and comprised many genera and species: a few million years ago this section of the plant kingdom fell from its high estate and is now represented by a single species. An attempt is made in the following pages, omitting unnecessary detail and technicalities, to present some of the evidence. The first part of this article is devoted to *Ginkgo biloba*, and closely related trees of the same genus which failed to persist until the present age. In the second part a short account is given of other genera included in the *Ginkgo* group that have long been extinct.

PART I

Ginkgo biloba

Ginkgo, like the Larch, is one of the few naked-seeded (Gymnosperm) trees that is deciduous; it reaches well over a hundred feet in height: the branches are spreading or steeply ascending. In the autumn the leaves assume an attractive golden colour before falling. In shape and venation the foliage is unlike that of any other tree; it is fan-shaped or triangular and varies considerably in size and shape. The specific name *biloba* was chosen because in many, though by no means all, leaves the blade is divided by a median V-shaped depression into two symmetrical halves. Leaves vary from about one inch to two or three inches in depth, and from one to three inches in breadth; they may reach a breadth of six inches, but this is exceptional. The slender leaf-stalk is one and a half or as much as two inches long. The lower margin of the blade may be almost straight and at right-angles to the stalk, or not infrequently in small leaves the outline is triangular, the two sides converging to the base: occasionally the lower margin has the form of a double ogee curve. The upper edge is rounded, entire, irregularly undulate, or bilobed. In some leaves, especially those on vigorous young shoots, the blade is often dissected by V-shaped depressions into four or more wedge-shaped segments. The deeply cut leaves with several cuncate lobes are reminiscent of the foliage of many extinct species. The range in size and shape of the foliage of the living species adds considerably to the difficulty of deciding whether or not certain fossil leaves should be regarded as specifically identical with *Ginkgo biloba*, or indeed one with another. Accurate comparison is impossible without the aid of supplementary evidence from structural features. Forked veins radiate through the leaf from the lower margin: the venation is very similar to that of the leaflets of a Maidenhair fern (*Adiantum*). Two strands of conducting tissue pass from the stem up the leaf stalk and branches from them form the spreading and forked veins. Here and there between the veins short tracts of secretory cells are easily recognizable as translucent patches when a leaf is seen in transmitted light, or as dark patches by reflected light. Similar secretory tracts are an almost constant character in the fossil leaves.

The leaves are borne on two kinds of shoot: long shoots which grow with relative rapidity and determine the shape of the tree; also short and very slow-growing shoots. On long shoots the leaves are scattered and spirally disposed, while on the short shoots about

six or fewer are borne as a cluster at the tip. The surface of a dwarf or short shoot is covered with crowded scars left by leaves of past years. Special attention is called to the short foliage-shoots because they are characteristic of many extinct members of the family; they are similar to the dwarf shoots of Larches and Cedars, and to the deciduous and smaller shoots of Pines.

Male and female reproductive organs are borne on separate trees. It is possible to obtain both kinds of "flower" on one tree by grafting a female branch on to a male tree: this operation was successfully performed some years ago on the large male tree at Kew. My friend, the Rev. Professor A. C. Moule of Cambridge, tells me that he discovered a passage in an old Chinese book advising the planting of male and female seeds close together in order to ensure fertilization at a later stage. This implies an uncanny power of distinguishing male from female even in the seeds. The male flowers—as it is convenient to call the reproductive shoots—are loose catkins bearing on a slender axis several short stamens, each of which has two or rarely three or even four pollen-sacs. The female shoots are longer and larger, each usually bearing a pair of ovules which develop into fleshy yellow seeds as large as cherries. In the Far East the Maidenhair tree is spoken of as the Silver Apricot. Within the fleshy covering a hard shell, generally with a prominent median keel, encloses and protects the embryo and the store of food prepared by parent for offspring. The kernel (embryo and food) is eaten in China and Japan as a delicacy: the outer flesh is nauseous.

Ginkgo, despite the difference in foliage, was formerly included with the Yew (*Taxus*) in the Taxineæ, one of the families in another group of naked-seeded trees, the Conifers. About forty years ago a Japanese botanist, Hirase, discovered that the sperms are free-swimming bodies of relatively gigantic size, provided with innumerable lashing cilia in marked contrast to the passive and microscopically minute male nuclei of Conifers. In view of this fundamental peculiarity, and having regard to other characters not found in Conifers, a new family and a new group, the Ginkgoales, were instituted for this isolated, aberrant, and primitive genus of naked-seeded plants. Thus *Ginkgo* came to be regarded as the single representative not only of a genus and family but of a group of Gymnosperms. There are many interesting points connected with the structure of the seed and other technical questions which need not be discussed as they have no direct bearing on the more general considerations with which this article is concerned. *Ginkgo* resembles Conifers in the main structural features of the wood; it

is indeed very difficult to decide whether or not some examples of petrified fossil wood should be assigned to the *Ginkgo* family or to the Conifers.

THE PRESENT HOME OF *GINKGO*

Some botanists believe that the Maidenhair tree is still living as a wild tree in certain Chinese forests ; others are definitely of opinion that it exists only in cultivation, the apparently wild trees being the offspring of parents planted by man. One thing is certain : *Ginkgo* has long been cultivated in China and Japan, and the oldest specimens occur in the neighbourhood of temples, so that it has sometimes been regarded as a sacred tree. Seeds have doubtless been dispersed by natural agency, producing trees at increasing distances from the parents : it is therefore not always easy to distinguish cultivated from wild specimens. English botanists and plant collectors who have travelled extensively in China say that they failed to discover the tree in forests remote from civilization. On the other hand, a few years ago a Chinese botanist recorded the occurrence of *Ginkgo biloba* in certain localities in the Chekiang province of eastern China : he wrote—" This tree is very common in Tienmu-Shan growing in association with Conifers and broad-leaved trees. It seems to grow spontaneously in that region." An affirmative reply to the question, does *Ginkgo* still exist in natural forests as a wild tree ? cannot be given with absolute certainty. It may still exist in places where man has played no part, and that is as much as can be said without reservation. There can be no doubt that China was the last, if it is not the present, natural home of the Maidenhair tree. It was brought to Europe in the early part of the eighteenth century ; to Utrecht about 1730, and to England a little later : the tree is now fairly common in European gardens, admired for its autumn colouring and the fern-like venation of the leaves. There is, however, another attribute which entitles it to our respect and protection : it is a remarkable and almost unique example of the extraordinary conservation and vitality through millions of years of a member of the plant kingdom whose forbears were forest trees ages before the birth of the human race, ages before the existence of our familiar broad-leaved trees, and antedating almost the whole of the Mammals. In comparison with most impressive man-made monuments, such as the step pyramid of Saqqara, which take us back to the dawn of civilisation, the records of plants preserved by nature in the sands and muds of former ages speak to us of a past beyond the power of human intelligence to appreciate. After reading the following summary

of the history of *Ginkgo* and its allies it will be easier to appreciate the reasonableness of describing the Maidenhair tree as one of the wonders of the world ; it has persisted with little change until the present through a long succession of ages when the earth was inhabited by animals and plants for the most part far removed, in kind as in time, from their living descendants. *Ginkgo* is one of a small company of living plants which illustrates continuity and exceptional power of endurance in a changing world. The *Ginkgos* that grew in western and eastern forests one hundred and two hundred million years ago were no doubt very similar in appearance to the species that alone survives ; they lived the same life, depending upon the light of the sun, the carbon-giving gas in the atmosphere, and the water in the soil exactly as trees of the present day. When we reconstruct the continents over which the forests spread and restore to life the contemporary companions of the old *Ginkgos*, continuity gives place to discontinuity ; land where there is now water and water over regions that are now land. As the wind spreads a kaleidoscopic pattern of lights and shadows over the massed branches of the tree, we cannot but be conscious of the contrast between the wind, that has blown since the earth began, and the varying nature of the old-time forests—

'Tis the old wind in the old anger
But then it threshed another wood.

When we regard the earth's surface in terms of the ordinary time-scale it gives us an impression of stability : adopting the time-scale of geologists we are able to measure the duration of earlier periods ; as we pass from one age to another we can follow the shifting boundaries of continents and seas. With minds prepared by thoughts derived from a geological retrospect *Ginkgo* becomes much more to us than a mere tree ; it speaks to us as an oracle recording in the trembling accents of its fluttering leaves the varying fortunes of its race and wanderings over the world's surface as age succeeded age ; it gives us glimpses of the great procession of life and the building of the world in which we live.

A NOTE ON THE NAME *GINKGO*

The name *Ginkgo* was coined by Kaempfer, who travelled widely in the Far East, for a tree he first saw in Japan in 1690. In 1712 in his book *Amœnitates Exoticæ*, he spoke of the tree as "*Ginkgo vel Gin an, vulgó Itsjo, arbor nucifera folio Adianto*," and published an excellent drawing of foliage-shoots and seeds. Linnaeus in 1771

adopted Kaempfer's generic name and called the plant *Ginkgo biloba*. In obedience to the rules of nomenclature governing botanical usage this is generally accepted. Twenty-six years later J. E. Smith proposed to substitute the generic name *Salisburia* for the "equally uncouth and barbarous" *Ginkgo* of Kaempfer; he also altered the specific name *biloba* to *adiantifolia*. Smith's proposal was made subsequent to the date accepted as the starting-point of botanical nomenclature and was therefore not adopted. The word *Ginkgo*, which *The Times* newspaper, in recent correspondence on the tree, preferred to spell Ginkgo, has been variously interpreted. In order to ascertain its true meaning I consulted my friend, the Rev. Dr. A. C. Moule, Professor of Chinese at Cambridge, who at once became interested and spared no pains to satisfy my curiosity. His extended researches have now been summarised in a paper published in *T'oung Pao*, Vol. XXXIII, Livr. 2 (E. J. Brill, Leiden).

The word *Gin* in Chinese means "silver" and Kaempfer thought that *Ginkgo* meant Silver Apricot. Professor Moule points out that there are no grounds for the termination *kgo*; the *g* cannot be explained and may be a slip in transcription, or *Ginkgo* may be a misprint for *Sankyo*, a word found by Professor Moule in one of Kaempfer's MSS. in the British Museum Library; it means Hill Apricot. The list of Japanese names which Kaempfer thought he was reproducing contains no such name as either *Ginkyo* or *Ginkgo*. The latter, Professor Moule writes, "is unpronounceable and probably ought never to have existed." But whatever the explanation of "*Ginkgo*" may be, the Japanese actually call the tree *Icho* (or *Itsio*) and the fruit Ginnan, and it is clear from Kaempfer's MSS. that he was well aware of this. For a full discussion of all the names readers should consult the authoritative paper on "*The name Ginkgo biloba*" in *T'oung Pao* (Vol. XXXIII, Livr. 3).

[I am also indebted to Professor Moule for much interesting information gathered from Chinese and Japanese writings and for notes contributed by his cousin, the Rev. G. H. Moule. A name for the Maidenhair tree used by authors in the early Middle Ages is Duck's foot: in the twelfth century a Chinese poet spoke of "the gold of the duck's foot leaves," referring to the autumn colour of the foliage. The Japanese believed that *Ginkgo* served as a protection against fire by exuding water when scorched: the Rev. G. H. Moule writes that he has seen *Ginkgo* trees blackened by flames and scarcely hurt while other trees were destroyed. The same writer refers to the hanging roots on stems of old *Ginkgo* trees in Japan which are said to symbolize women's breasts: he speaks

of a tree at Sendai ¹ which has been worshipped for more than a thousand years by women suffering from lack of milk and any sickness of the breasts].

THE PAST HISTORY OF *GINKGO*

Let us first examine the nature of the evidence which enables us partially to reconstruct the past history of *Ginkgo* and other members of the Ginkgoalean group. Incomplete and fragmentary as it is, there is material enough to provide the outline of a fascinating story. It is fortunate that the leaves of *Ginkgo* can as a rule be recognised in a fossil state without much difficulty or danger of confusion with the foliage of other plants. Leaves are the chief source of our knowledge: seeds and other remains are rare and supply little more than confirmatory evidence. Form and venation and, whenever possible, the minute structure of the surface layers of leaves furnish the necessary data. A fossil leaf may agree very closely in shape and venation with leaves of the living plant; but that in itself is not proof of specific identity. Fortunately many fossils are not mere impressions on shale and sandstone—ghosts without substance; they are often covered with a black or brown film which is all that remains of the tissues. This film represents the altered or carbonised remains of the leaf substance: its surface is the resistant cuticular skin which covered the epidermal layer of the living leaf. The film can often be detached from the rock, or it may peel off naturally. By treatment with appropriate reagents it is rendered less opaque and becomes amenable to microscopical examination, revealing the cell-pattern of the epidermal layer, including the minute and vitally important stomata. The stomatal apparatus, which regulates gaseous exchange between the plant and the atmosphere, serving also as an exit for water-vapour, has a characteristic structure of great value in distinguishing one genus or family from another. Focussing below the surface of the film one can sometimes see the remains of underlying tissue, crushed and contracted, and readily detect the presence of secretory cells still containing dark patches of the original products of secretion. Thus valuable evidence is obtained enabling us to compare in detail the surface-layer and some of the deeper tissues with the corresponding structures in fresh leaves. By the use of modern methods of technique it has been possible to correct conclusions based solely on external form. Botanists

¹ For a photograph of the Sendai tree see *Plant Life through the Ages* (A. C. Seward, p. 521, Fig. 135.)

concerned only with living plants naturally and very properly attach the greatest importance to reproductive organs as criteria of relationship. The palæobotanist is in a much less favourable position ; he hardly ever finds fossil leaves and flowers preserved together, and indeed flowers are seldom available ; he has therefore been compelled to make the best use he can of leaves, and has studied them intensively. In rare instances it is possible to examine not only the surface-layer of fossil leaves but the structure of all the tissues : leaves and other parts of plants occasionally occur as petrifications, preserved in amazing perfection. Petrified leaves are abundant in the calcareous nodules of coal seams (Carboniferous period), but in rocks belonging to periods in which the *Ginkgo* family flourished they are exceedingly rare. One of the few examples of Ginkgoalean foliage preserved in this way is mentioned on a later page.

Nearly thirty years ago the writer suggested the employment of the generic name *Ginkgoites* in place of *Ginkgo* for fossil leaves which through lack of evidence cannot be regarded as generically identical with *Ginkgo biloba*. Fossil leaves closely resembling the foliage of the Maidenhair tree may have belonged to a tree having male and female flowers which differed in some important respects from those of the surviving species. Palæobotany is not an exact science : the documents which the student endeavours to decipher provide only scraps of information, and it is desirable that this lack of precision and paucity of evidence should be implied by the terminology which a palæobotanist employs. If he has sufficient evidence to justify him in assigning fossil leaves to the genus which includes *Ginkgo biloba*, well and good ; if he has no such evidence, then he admits the lack of certainty by adopting the name *Ginkgoites*. It is, however, impossible in some instances to make a satisfactory choice between the alternative generic names. For present purposes it is not worth while to discuss tiresome though unavoidable questions of nomenclature : for the sake of simplicity, rather than in accordance with strictly scientific considerations, the generic designation *Ginkgo* is adopted in the following account of fossil leaves believed to belong to trees which, if now living, would either be referred to *Ginkgo* or to a separate and very closely related genus of the same family.

FOSSIL LEAVES

The periods of geological history with which we are concerned are arranged as follows :

Recent

Quaternary

Tertiary	{	Pliocene	stage
		Miocene	„
		Oligocene	„
		Eocene	„
Cretaceous			
Jurassic			
Rhætic			
Triassic			
Permian			
Carboniferous			

As already stated, it is not absolutely certain, though by no means improbable, that the Maidenhair tree still exists as a wild tree : there can be no doubt of its natural occurrence in Far Eastern forests within the limits of the Recent period. Passing to the Quaternary period, to a time separated from the present by many thousand years, there is a record of the discovery of *Ginkgo* leaves by the Russian palæobotanist Kryshtofovich at a locality on the Bureya River in north-eastern Siberia (approximately 50° N. lat.) : good photographs of the fossils have not been seen. Descending the geological scale the next records are from Pliocene plant-beds in France and Germany. Well-preserved leaves were found near Frankfurt-on-Main very similar in form and venation to the leaves of *Ginkgo biloba*, agreeing also in the structure of the epidermal layer, though not identical in certain details. Other examples from the Pliocene stage have been described from the Rhone Valley, where forests formerly fringed the shores of a large gulf occupying the site of the southern part of the present river's course. These fossil leaves, superficially indistinguishable from the foliage of the living tree, with many others from Tertiary rocks, are usually spoken of as *Ginkgo adiantoides*. Specimens have been obtained from rocks belonging to all stages of the Tertiary era, particularly from the earlier or Eocene strata. Some of the most beautifully preserved leaves are from the Island of Mull, where they were collected many years ago from sedimentary deposits associated with the horizontal sheets of basalt which give the characteristic terraced profile to some of the Inner Hebrides. In the early days of the Tertiary period, subsequent to the upheaval of the floor of the Cretaceous sea, volcanic forces, which had long been dormant, broke out into activity on a stupendous scale : through fissures in the earth's crust and from volcanoes sheets of lava spread over an enormous area including north-east Ireland, the Inner Hebrides, the Faröes, Greenland and other arctic regions. The columnar basalts of the Giant's Causeway in northern Ireland and Fingal's

cave in the island of Staffa belong to this Tertiary lava-field. The occasional occurrence of water-borne sedimentary material intercalated among the sheets of lava, as in the island of Mull at Ardtun Head on the south-west coast, bears witness to periods of quiescence during which forests were able to colonise the lava-fields. *Ginkgo* was one of the forest trees. The leaves were first described by the late Mr. Starkie Gardner about fifty years ago, who spoke of them as indistinguishable from those of the living tree. Realising that plants as old as the Eocene stage of the Tertiary period—a stage separated from the present by perhaps eighty million years—were probably not specifically identical with those of the present day, he referred the Mull fossils to the Tertiary species *Ginkgo adiantoides*. A recent examination of the epidermal cells of the Mull leaves by Dr. Florin of Stockholm revealed certain peculiarities which led him to re-name the species *G. Gardneri*. We do not know anything of the “flowers” of this species; but it is safe to assert that the Mull tree was very closely allied to *G. biloba*.

Since the discovery of fossil *Ginkgo* leaves in Tertiary rocks of northern Italy, nearly a hundred years ago, numerous specimens from Eocene and later rocks have been described from widely separated localities in arctic and temperate regions. The significant fact that emerges from a review of the evidence furnished by rocks of the Tertiary period is that species of *Ginkgo*, how many we do not know, had a far-flung geographical range: the genus was represented in forests from the Pacific coast of North America to Alaska and arctic Canada; in western and eastern Greenland as far north as latitude 74°, where leaves have been found in Tertiary rocks of Sabine Island. With many other trees *Ginkgo* flourished in Spitsbergen, in the forests of Siberia and as far east as the western shores of the Pacific ocean. Its territory was spread over wide tracts in both the Old and the New World, mainly in the northern hemisphere. It is, however, significant that in 1935 Professor E. W. Berry of Johns Hopkins University recorded the discovery of Tertiary *Ginkgo* leaves in Patagonia. This fact affords impressive proof of the enormous distance over which *Ginkgo* trees had been dispersed. Tertiary records are not all from rocks of the same geological age; most of them are from the Lower Tertiary, the Eocene stage; some from Miocene and Oligocene rocks and a smaller number from the uppermost, or Pliocene stage, of the period. As the ages of the Tertiary period passed the geographical range of the genus became more restricted until, so far as we know, only a single species remained when the Recent period began.

There is no clearly marked difference in the position occupied

by the genus in the living garment of the Cretaceous earth ; it was very abundant as far back as the older Cretaceous floras. The chief difference is that as we descend from the Tertiary to older periods we find a gradual increase in the number of other genera of the *Ginkgo* family. Confining attention for the moment to *Ginkgo*, it is interesting to find in rocks corresponding in age to the sediments deposited in the great Wealden lake of southern England, northern France, Belgium and northern Germany leaves very similar in external characters to those of the Maidenhair tree. Such have been discovered in Lower Cretaceous strata in Alaska, western Greenland, Franz Josef Land, north-west Germany, northern France, and elsewhere. Fossils gathered from the sedimentary beds of the still more ancient Jurassic period at many localities in both hemispheres demonstrate an almost world-wide distribution of *Ginkgo*. Some of the leaves from the Jurassic rocks near Scarborough bear a striking resemblance in size, shape, and venation to the modern type of foliage and differ only in comparatively minor structural characters. Without discussing precise correlation of plant-bearing beds within the long period embraced by the Jurassic system with its several sub-divisions, it can be said with confidence that *Ginkgo* had by that time reached its maximum in abundance and geographical range. There were *Ginkgo* trees in Jurassic Australia, New Zealand, Afghanistan, Turkestan, Siberia, many parts of China, also in Japan and Korea. It grew in southern Russia, in Sardinia, and throughout Europe ; it had wandered as far west as Oregon on the Pacific coast. A few specimens from Jurassic rocks of India have been assigned to *Ginkgo*, but these are less satisfactory as records than those from other regions. It is noteworthy that neither *Ginkgo* nor any other member of the family has been found in the rich Jurassic flora described some years ago from Grahamland, which members of the recent Grahamland expedition have proved to be a peninsula of the Antarctic continent and not an island as previously supposed. The flora of Grahamland is exceptional among floras of the Jurassic age in the lack of any members of the *Ginkgo* group.

Many floras have been described from Greenland, southern Sweden, Germany, Poland, Indo-China, South Africa, and Australia as Rhætic in age : the rocks so called are intermediate in geological position between the Jurassic and the preceding Triassic period ; some correspond more closely with rocks of the Lias stage at the base of the Jurassic ; some are closer in age to the upper members of the Triassic system. One of the oldest leaves, which it is permissible to speak of as a species of *Ginkgo*, is from Rhætic rocks in

southern Sweden : it agrees in the main with the modern leaves both in epidermal structure and in venation. Leaves apparently representing four species have been described from an Upper Triassic flora in South Africa ; this is one of many indications of the abundance of trees having foliage constructed on the *Ginkgo* plan at a stage in the history of the earth when strange reptilian animals were the lords of creation. One of the South African species is almost identical in shape, size, and venation with leaves previously described from rocks of approximately the same age in Virginia. The leaves had a lamina partially divided into linear segments varying in size and reaching nearly one foot in breadth. The same species has been found in Upper Triassic rocks of Queensland. The exceptionally rich flora described in a series of remarkable papers by Professor Harris of Reading from material he collected, 1926-27, in the Scoresby Sound district (slightly north of lat. 70° N.) on the east coast of Greenland includes at least six species of *Ginkgo*. Some of the leaves bear a close resemblance to the Maidenhair foliage not only in shape and venation but in the occurrence of secretory sacs. One of the species is peculiar in having leaves dissected into four lobes with toothed upper margins, a very unusual character. It is certain that trees with various forms of leaf more or less similar in plan to those of the Maidenhair tree lived in the latter part of the Triassic period in South Africa, Argentina, Queensland and the northern hemisphere. It is important to remember that the name *Ginkgo* has been used in the foregoing account for some leaves which should, strictly speaking, be assigned to *Ginkgoites*. This brief and incomplete review of fossil leaves of many ages and from many parts of the world is sufficient to justify the statement that the existing species is the last of a long line of predecessors reaching back to the latter part of the Triassic period, a stage in geological history at least one hundred and fifty million years ago.

Having followed the story so far it is natural to ask how much farther into the past has the history of *Ginkgo* been traced ? Assuming, as we do, that this generic type did not suddenly appear as a novelty in the plant kingdom, where did it come from and of what sort were its ancestors ? Such questions as these are ever present in the thoughts and speculations of the curious people who search for origins among the scanty and often illegible documents scattered through the rocks in the course of geological history. As we follow a group, a family, or a genus through the pile of sedimentary rocks we reach at length the earliest records, and though it may seem that the quest is ended, there always remains doubt and uncertainty whether the lack of still older fossils may be due to imperfection

of the record. It was only in exceptional circumstances that samples from nature's garden were preserved in the herbaria of the rocks: As we pass from rocks containing the most ancient fossils that can be regarded with confidence as undoubted allies of the Maidenhair tree to rocks older still, we discover fossil leaves which may or may not be the foliage of trees of the same lineage. Leaves from Permian and Carboniferous strata described under various names, *Ginkgophyllum*, *Psugmophyllum* and others, though similar in form to those of *Ginkgo*, do not afford definite evidence of real affinity. The most promising of the Palæozoic genera is known as *Saportea*, called after a French palæobotanist, the late Marquis of Saporta, a genus founded on leaves first discovered in Permian rocks of Virginia and more recently in Central China: this genus may be allied to *Ginkgo*; but that is as far as one can go. The ancestral stock may be recognised some day in the petrified litter of the coal period forests; but as yet we can only guess whence the *Ginkgo* group came. We must for the present be content with the knowledge that trees of the *Ginkgo* type had risen to prominence before the close of the Triassic period and continued to flourish and occupy fresh territory in the course of the Jurassic period: they held their own in the Cretaceous period and in the earlier stages of the Tertiary era, but as the Quaternary age dawned comparatively few examples remained.

PART II

Other Members of the Ginkgo Family

Each of the families to which botanists have assigned the higher plants, both Angiosperms and Gymnosperms, usually contains several genera differing, it may be, widely in appearance and yet possessing certain features in common believed to be indicative of close relationship. It is generally agreed that such trees as Larches, Cedars, Firs, and Pines are all members of one family which in the course of time have deviated in their several ways from some ancestral prototype. These genera are believed to be closely related one to another because they possess in common certain features, especially those exhibited by the fertile shoots, which suggest descent from a single ancestral stock. In attempting to classify fossil plants on a basis of natural affinity we have in most instances to use vegetative characters alone; and this is the method followed in the comparison of leaves of extinct plants with the foliage of recent species. There are very few families of plants represented in present-

day floras to which only a single genus is allotted. *Ginkgo* is one of the few living genera which has a family and indeed a whole group to itself. It stands alone with no near relatives: if nothing were known of its past history it would no doubt be regarded as an old type because of the possession of certain primitive traits. Search among the débris of forests embedded in the rocks has demonstrated that the genus was formerly one of several distinguished by characters indicative of community of descent. In order to illustrate this aspect of the present historical enquiry it is necessary to devote a few pages to a sketch of the main results of palæobotanical research into the family history of *Ginkgo* without going into technical detail.

The first genus to be considered is one known as *Baiera*: this name (after J. J. Baier, an early eighteenth-century German writer on fossils and minerals) was given as long ago as 1843 to leaves found near Bayreuth in Rhætic or Lower Jurassic rocks. In outline the leaves of *Baiera* are fan-shaped or triangular as in *Ginkgo*, but the lamina is more deeply divided into linear segments, few or many in number. It is not always possible to draw a satisfactory line between *Baiera* and *Ginkgo* from the form of the lamina alone. The leaves of *Ginkgo biloba* and those of extinct species have a fairly long and well-defined stalk: in those assigned to *Baiera* the leaf-blade is attached directly to the branch by a narrow, tapered base and lacks a leaf-stalk. In a typical *Baiera* leaf the blade is cut by deep V-shaped sinuses into narrow, linear lobes or segments, each of which is supplied with a few parallel and occasionally forked veins. Some species bore the leaves in tufts on very short shoots; in others the leaves were attached singly as in the long shoots of *Ginkgo*. It may be that some *Baieras* had both long and short shoots. In the structure of its epidermal cells, including the stomatal apparatus, *Baiera* is near enough to *Ginkgo* to be included in the same family. No undoubted example of *Baiera* has been found either in Tertiary rocks or in those belonging to the later stages of the Cretaceous period. A few species are recorded from the earlier Cretaceous beds, but some at least of these might more appropriately be assigned to *Ginkgo*. The genus was abundantly represented in both Jurassic and Rhætic floras and in many parts of the world, reaching as far north as lat. 70° N. in East Greenland. Some unusually large leaves have been described from Upper Triassic beds in North America, South Africa, and Australia. The oldest leaves believed to be examples of the genus are from Permian rocks. There is no doubt that *Baiera* was a companion of *Ginkgo* in Jurassic and Triassic forests and had a wide geographical range.

Its reproductive organs, so far as we know, conformed in essentials to the *Ginkgo* plan.

Another genus is *Ginkgodium*, characterised by leaves similar in venation to those of *Ginkgo* but narrower and rather different in shape: leaves of this generic type are comparatively rare; they were first described from Jurassic rocks in Japan nearly fifty years ago, and, later, recorded from Jurassic rocks in southern Russia. Nothing is known of the structure of *Ginkgodium* and for that reason the genus is of secondary importance. In 1913 Dr. Hamshaw Thomas discovered a new type of fossil in a Jurassic plant-bed in western Yorkshire, to which he gave the generic name *Eretmophyllum*. The leaves, four or five inches in length, are in shape like a rather narrow-bladed paddle, hence the name, from the Greek word *eretmon* = oar or paddle. The lamina has several parallel veins and resin-sacs; the structure of the superficial layer is consistent with close affinity to *Ginkgo*. Other examples of the genus are recorded from Jurassic rocks in southern Russia, Afghanistan, and Sardinia. Despite the lack of reproductive organs it is generally believed that the leaves known as *Ginkgodium* and *Eretmophyllum* may be safely included in the *Ginkgo* group.

We now come to some genera which differ more widely in form from those of the living Maidenhair tree but are confidently accepted as allies that have long been extinct. The name *Phaenicoopsis* (from the Greek *Phoinikeios* = of the date or palm tree) is applied to leaves comparable in shape to pieces of ribbon a few inches long and varying from half an inch to rather more or less in breadth; the veins are approximately parallel and occasionally forked. A characteristic feature of this and certain other genera is the occurrence of leaves in a crowded bunch on a very short shoot which is clasped and hidden by tiny overlapping scales: the scales protected the shoot when it was a bud and as the bud expanded they persisted at the base of the leaf cluster. *Phaenicoopsis* leaves have been described under several specific names and from many parts of the world; Siberia, Afghanistan, Turkestan, China, Japan, Spitsbergen, southern Sweden, Greenland, numerous European localities, including Great Britain, and elsewhere. The genus was very widely spread in Jurassic floras and it was also a member of Rhætic and early Cretaceous floras; it probably existed as far back in the geological time-scale as the Permian period. It has been possible to investigate the epidermal structure of several species of *Phaenicoopsis* and the facts thus obtained confirm the opinion of Oswald Heer, who in 1876 was the first palæobotanist to describe this old type of Ginkgoalean foliage. The very short branches, each bearing

a tuft of six or more grass-like leaves, may be compared on a small scale with the short shoots of the Maidenhair tree on which a cluster of stalked leaves is borne at the apex. There is, however, this difference: in *Ginkgo* the short branch persists from year to year and bears fresh leaves each season: in *Phœnicopsis* the dwarf foliage-shoot was probably shed every autumn or after a year or two; at all events, it bore only one set of leaves. Comparison may also be made with the dwarf shoots of Pines with two, three, or five needles; the chief difference is that the leaves of *Phœnicopsis* are broader and flat, and the structure of the epidermal layer is of another type. It has been customary to assign to this genus fossil leaves having a certain form and venation and borne in clusters, even though the material does not furnish any information on microscopical characters. Dr. Florin of Stockholm has recently described a number of leaves from Lower Cretaceous rocks associated with the basaltic lavas of the now treeless Franz Josef Land (lat. 80° N.) which, owing to their exceptional preservation, it was possible to examine in detail and elucidate their anatomical structure. He found that some leaves, though externally agreeing with *Phœnicopsis*, were sufficiently distinct in structure to be recognised as different genera.¹ One of the new genera is *Stephenophyllum*, named after Cape Stephen on the south coast of Franz Josef Land, where the specimens were discovered. Seven narrow, strap-like leaves are borne on a diminutive axis surrounded at the base of the dwarf shoot by persistent bud-scales. In appearance the foliage-shoot closely resembles a *Phœnicopsis*, but distinctive anatomical features are believed to justify the institution of a new generic name. Another genus, *Windwardia*, named after the ship *Windward* chartered by the Jackson-Harmsworth Expedition of 1896, whose members collected the material, bore dwarf, deciduous shoots each with five or seven linear leaves about five inches long, distinguished from those of other Ginkgoalean trees by the absence of secretory ducts and by a few other anatomical peculiarities. A third genus instituted by Florin is *Culgoweria*, a Scottish type, so called after Culgower in Sutherland, a locality from which a collection of Upper Jurassic plants, made by the late Dr. Marcus Gunn, was described by myself in 1911. Leaves that were originally assigned to *Phœnicopsis* on the ground of external resemblance have now been examined microscopically and found to differ in certain structural features from other members of the family.

¹ A short account of Dr. Florin's admirable contribution was published in *Nature*, May 1, 1937.

Dr. Florin's intensive study of the Franz Josef Land material led to the discovery of two more genera in this arctic flora, *Sphenobaiera* and *Arctobaiera*, both of which, as the names imply, are similar in the external characters of the foliage to *Baiera*. *Arctobaiera* is characterised by deeply divided tongue-shaped leaves borne in a tuft and not singly: *Sphenobaiera*, a genus founded on a piece of leaf, is distinguished by a greater degree of lobing: both show distinctive anatomical characters. Whether or not the Franz Josef Land leaves are all worthy of generic rather than specific status, it is clear from Dr. Florin's careful and illuminating researches that they furnish convincing evidence of a greater range in structural details within the *Ginkgo* alliance than was previously suspected. The main point is that there were several trees in the Jurassic and early Cretaceous forests with foliage-shoots superficially very much alike, but differing one from another in certain external and internal features; all agree more closely with *Ginkgo* than with any other living plant. It is noteworthy that Florin's genus *Sphenobaiera* has been recognised by Professor Harris as one of several members of the *Ginkgoalean* group in the Lower Jurassic-Rhætic flora of East Greenland.

Reference has already been made to the amazingly rich flora first discovered by Dr. Hartz of Copenhagen in Rhætic strata at Scoresby Sound in East Greenland and more recently investigated with great thoroughness by Professor Harris, who collected a large amount of new material. The flora included many representatives of the *Ginkgo* family, new species of genera previously recorded from other regions and, in addition, a new type to which the name *Hartzia* has been given. This genus, like many of the others, bore its long and relatively narrow leaves in groups on dwarf shoots, but the lamina of each leaf had a forked tip. The stomata differ in arrangement and structure from those of *Phenicopsis*.

Torellia.—This generic name, after Professor Torell, a geologist, was given nearly sixty years ago to leaves discovered by Captain Feilden, a member of the *Alert* and *Discovery* arctic expedition (1875-76) in early Tertiary rocks in Grinnell Land (81° 46') and subsequently recorded from Spitsbergen. The leaves of *Torellia* may be compared with broad and stiff blades of grass two or three inches long, furnished with several parallel veins, tapering to a narrow base and rounded at the tip. In some forms the blade is sickle-shaped. *Torellia* has since been found in Cretaceous rocks of Ussuriland in eastern Siberia. The genus was in existence as long ago as the Rhætic period in the forests of East Greenland. It is noteworthy that Dr. Florin, after examining the structure of *Torellia*

leaves from Spitsbergen, decided to remove them to a new genus, *Pseudotorellia*, because of certain distinctive characters.

Czekanowskia.—In 1876 Professor Heer of Zürich described some very narrow, almost hair-like leaves from Jurassic rocks in Siberia, which he named *Czekanowskia*, after the geologist Czekanowski, and referred to the *Ginkgo* family. Data subsequently obtained confirm Heer's estimate of affinity. The leaves were attached to a very short, scale-covered axis and borne in a cluster, resembling the bunch of leaves of a five-needled Pine: each leaf has two or more veins forked once or more. Several species of *Czekanowskia* are known from Jurassic rocks in arctic regions, Europe, and Asia. In epidermal characters the leaves conform more closely to the *Ginkgo* pattern than to that of any other surviving Gymnosperm.

Nothing has been written in this article on seeds or other reproductive organs associated with Ginkgoalean leaves in widely scattered parts of the world and in rocks of many ages: this is not because they are unimportant; they are of the greatest value to the palaeobotanist. The reason is that it is seldom possible to connect together leaves and reproductive organs, owing to the fact that they are preserved in the sediments of estuaries and lakes as separate scraps which fell from the parent trees and were carried by rivers to their resting-place. It is, however, important to note that the remains of such reproductive organs as it has been possible to examine with any degree of thoroughness, furnish valuable data supplementary to evidence of affinity obtained from foliage-shoots.

THE WORLD-WIDE WANDERING OF *GINKGO* AND ITS ALLIES

A survey of the voluminous publications in which are recorded discoveries of fossil plants referred on good evidence to the *Ginkgo* alliance demonstrates the extraordinary vitality and resiliency of the genera and their success as travellers over wide spaces. It would extend this sketch far beyond reasonable limits were reference made to all the species and the places where they have been found. It is also impossible in a general summary to make comparison of the distributional areas of the several genera. The black dots on the map (Fig. 1) indicate localities where members of the family have been found in rocks ranging from Triassic to the end of the Tertiary period. Though by no means a complete record, the map serves to illustrate the light thrown by palaeobotanical data on the wanderings of these Ginkgoalean trees never seen in life by man and known only as fragments preserved in the rocks. The tenacity with which a single member of this once vigorous group held on

to life through the ages has enabled us to read the story of its ancestry.

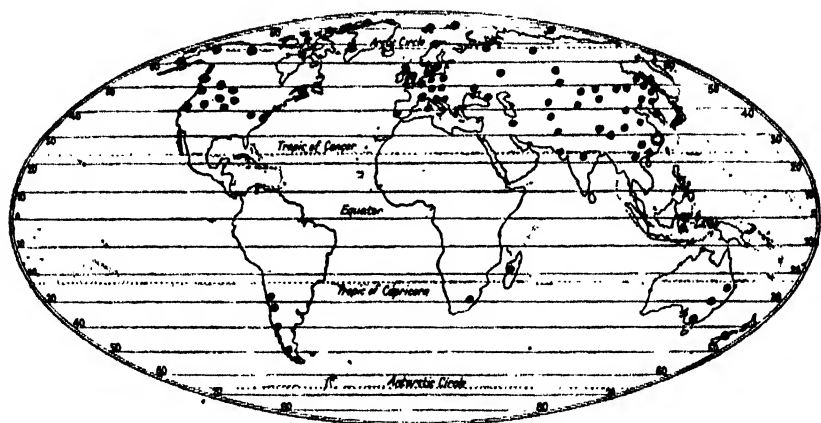


FIG. 1.—Map of the distribution of *Ginkgo* and allied genera in former periods of geological history. The area within which *Ginkgo* may still exist as a wild tree is shown by the circle below 30° N. lat. on the eastern edge of China. The records on which the map is based are from the Triassic to the Quaternary period.

CONCLUSION

In the foregoing pages my purpose has been to present the more important results of research into the history of the *Ginkgo* family. *Ginkgo biloba*, the Maidenhair tree, is worthy of special regard as one of the most impressive examples in the plant kingdom of a link with remote ages and as the sole representative in the modern world of a family, which millions of years ago occupied as prominent a place in the vegetation of the world as that now held by the oaks and other familiar forest trees included in the oak family. Omitting any further reference to the Palæozoic fossils, mentioned on a previous page as possible though doubtful members of the Ginkgoalean stock, the main historical conclusions may be summarised as follows (see Fig. 2.)

As the Triassic period drew to its close more than one hundred and fifty million years ago, the surface of the earth bore little or no resemblance to that with which we are familiar. At that stage in geological history and during many million years that followed the distribution of land and water, mountains, valleys, and plains, animal and plant communities, and climatic conditions reflected in their gradual transformation the cycles of physical and organic evolution. Even in the Triassic period there were a few plants foreshadowing more or less clearly trees that are still living. Con-

spicuous in this small company were representatives of the Ginkgoalean family, notably *Baiera* and *Ginkgo*. Passing upwards to the Jurassic period we find other genera added to the growing family, genera which established themselves over a vast extent of territory both north and south of the equator. It was at this

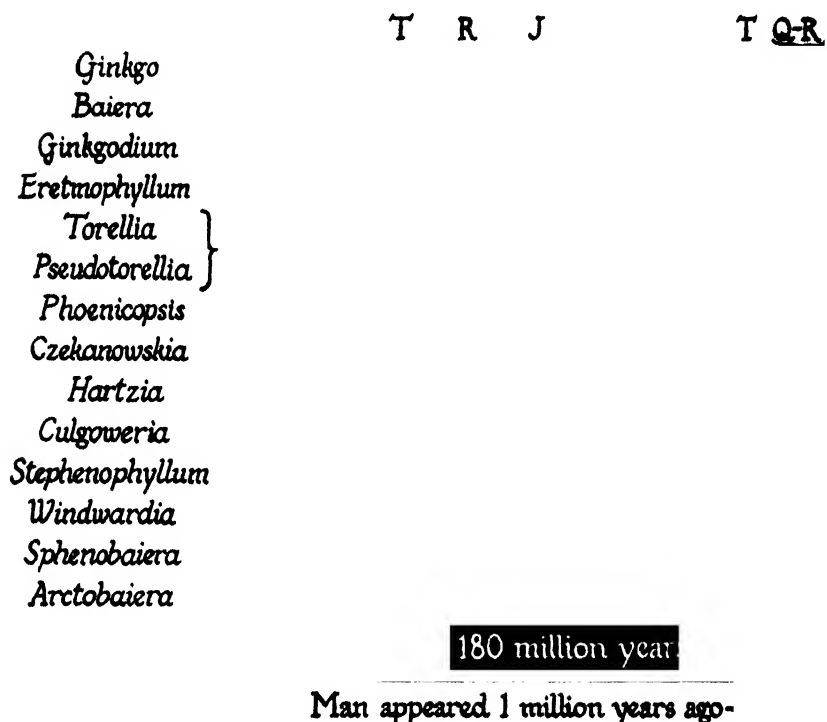


FIG. 2.—Diagram illustrating the approximate distribution in time of genera of the Ginkgoales.

P - Q - R = Permian, Triassic, Rhætic, Jurassic, Cretaceous, Tertiary, Quaternary and Recent periods. The relative antiquity of the Ginkgoales and the human race is indicated by the black time-scale. According to the late Professor Elliot Smith (*Human History*) man "must have been alive during the Pliocene stage." Professor A. Holmes (*The Age of the Earth*) gives the date of the Triassic period as 180 million years. The name *Ginkgo* is used in a wide sense, including some species which should be assigned to *Ginkgoites*. It is important to note that the genera *Stephenophyllum* and others shown in the Table as Lower Cretaceous were founded on exceptionally well-preserved fossils from Franz Josef Land: in all probability, were equally good material available from other places, they would be found to have had a much greater range in time and in space. The diagram is not drawn to scale except that the Rhætic period, transitional between the Triassic and Jurassic, is shown as a shorter phase of geological history.

stage in the history of the earth that *Ginkgo*, *Baiera*, *Phœnicopsis*, *Czekanowskia* and other genera reached their greatest development as measured by the number of species and geographical range. As the Jurassic period merged into the Cretaceous the balance of nature was not seriously disturbed: many genera survived the change. But the Ginkgoalean race had passed its zenith. There followed

a much more drastic physical revolution when the Cretaceous sea, in which the material of our chalk downs was made from the calcareous skeletons of marine creatures, flooded vast continental areas—a revolution which had a far-reaching effect upon contemporary life.

When the floor of the Cretaceous sea had been raised into land and the calcareous ooze of the ocean was converted into hills of chalk, the plant-world assumed a much more modern aspect. In the Tertiary floras preserved in sedimentary deposits of post-Cretaceous age *Ginkgo* was almost, though not quite, the sole survivor of the family; it was still a vigorous and widely dispersed tree in American, Arctic, European, and Asiatic forests. Even as late as the last, or Pliocene, stage of the Tertiary period *Ginkgo* still lingered on in Europe. It is probable that the genus was unable to endure the severe arctic conditions which swept over an enormous area in the Old and the New World when the genial climate of the Tertiary age was followed by a glacial phase. *Ginkgo* lived on in the Quaternary period, the sole relic of a race threatened with extinction. Driven hither and thither by adverse circumstances, this symbol of departed glory eventually found a refuge in the Far East. It was not until the family had been reduced to a few species and a single genus that man came into the world, and in a later stage of his development assisted nature by his care of one of her oldest treasures.

Ginkgo has for centuries appealed to the imagination of the Oriental mind: the tree with leaves like golden Ducks' feet became an object of veneration; a legacy, it might be, from a golden age and as such possessing miraculous power. We, despite our more matter-of-fact western outlook, pay homage to the sacred tree of the East because its story, written in the sands of time, gives us a vision of enduring life. The Maidenhair tree appeals to the historic soul: we see it as an emblem of changelessness, a heritage from worlds of an age too remote for our human intelligence to grasp, a tree which has in its keeping

“The secrets of the immeasurable past.”

AIR RESISTANCE AND ITS EFFECT ON AEROPLANE SPEEDS

By G. T. R. HILL, M.C., M.Sc., M.I.MECH.E., F.R.A.E.S.

Kennedy Professor of Engineering in the University of London, University College.

To the casual observer, all modern aeroplanes look alike. Large aeroplanes appear to be just small ones scaled up ; closer examination reveals the presence of two or four engines projecting in front of the wings on the larger types, but it is undoubtedly true to say that at the moment the external shape of new types of aeroplane is becoming stabilised ; it takes the form of a single wing, tapered towards the tips, running through a well-streamlined body, at the rear end of which a horizontal and a vertical surface is mounted like the feathers of an arrow. No means of making contact with the earth are visible, unless we are looking at a seaplane, where, again to the casual observer, a small float under each wing is the only apparent indication that the designer has remembered that all flights have a beginning and an end.

Twenty years ago, during the Great War, we saw a far wider diversity of design ; there were aeroplanes with one plane, and with two, three and even four planes one above the other ; there were propellers pushing behind, or those pulling in front ; there were under-carriages with two, three and four wheels ; there were thin and thick wings, while the methods of construction were, as might be expected in such varying designs, somewhat startling to an "orthodox" engineer.

This change from variety towards a common standard is to be observed particularly in mechanical devices ; the motor-car, for instance, has passed through these stages in the lifetime of many of us, and it is worth while studying those forces which bring about this "stabilisation" of design. My own feeling is that in nearly all cases it would be right to say that a truer understanding of the nature of the problem in design is the main factor which curbs the wilder flights of imagination of the designer. In the design of aeroplanes, I should say that a clearer understanding of the nature of air resistance has been that main factor making for stabilisation.

Lanchester in England formulated the theory connecting the lift required to maintain flight and the drag, or resistance to forward motion, necessarily associated with it. This drag is now known as "induced drag." For many years nobody in England took his work seriously, but Prandtl in Germany developed the theory, and some twelve years ago designers began to make use of it. Then in 1929 Jones of Cambridge, in a remarkable paper before the Royal Aeronautical Society, pointed out very clearly how the drag of an aeroplane should be subdivided, making it plain that just as there must be drag necessarily associated with lift, so there must be more drag, called "skin friction," necessarily associated with the total "wetted area" of the aeroplane, that is the area of all the surfaces exposed to the air flow. Further than this he emphasised that this "necessary" drag formed but a small part of the drag of the best designs of that time, and that the bulk of the drag was due to imperfect design from the point of view of producing a stream-line shape.

Designers at this time were not unaware of this, since their tests of models in wind tunnels showed them that the drag of the whole model was several times greater than that of the wing above; the reason for this was, of course, the presence of such things as windscreens and cylinders exposed for cooling, which gave rise to large eddies and high drag. Comparison with Jones's ideal "stream-line aeroplane" which had no drag other than "induced" and "skin friction" seems to have provided a great part of that stimulus which has produced such astounding results in so short a time.

Of course, other factors of importance must not be overlooked. Just as the improvement of the quality of rubber has had a far-reaching effect on the popularity of the motor-car, so in aeronautics we have seen the successful advent of higher wing loadings made possible by more reliable engines, and high lift devices to compensate for reduced wing area; while improved lateral stability at slow speeds and the controllable pitch propeller have played their parts.

Returning to the analysis of drag, it may seem curious to say that induced drag and skin friction drag are the only unavoidable retarding forces. Leaving for the moment the question of keeping the engine cool, which ordinarily costs something in drag, surely the bulkiness of the body or wing, as seen in front view, must have some adverse effect?

In a perfect fluid, *i.e.* one where the viscosity is zero, there would be no drag due to the bulk, or form, of the object pushing the fluid out of its way. Thinking for the moment of an airship shape, let us follow the air as it passes near the surface; first,

the stream separates as it meets the body and is bent outwards, then it starts to curve the other way and along most of the length of the shape it is following the curvature, i.e. bending inwards, and lastly near the tail it must stop converging and bend the other way into a straight path in the general direction of motion. Each of these three stages is associated with appropriate normal pressures on the body, i.e. positive pressure on nose and tail where the

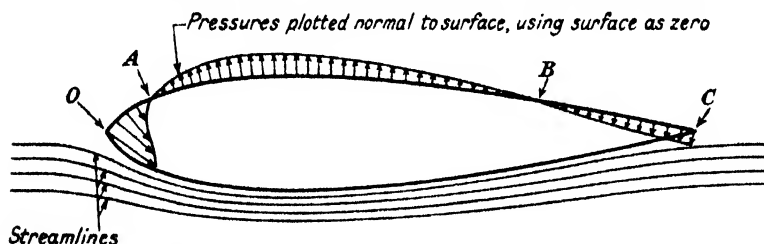


FIG. 1.—Pressure distribution and streamlines for airship shape.

Regions of Positive Pressure O—A and B—C, streamlines bending from centre line.
Regions of Negative Pressure A—B, streamlines bending towards centre line.

streams are curving away from the centre, and negative pressure or suction over most of the surface where the stream is curving back towards the centre. Now the longitudinal components of all these pressures are directed some forwards and some aft, and it is not difficult to appreciate that a condition of balance is possible, with all forward components cancelling all backward components, and in a perfect fluid, this balance would be achieved.

Air does, however, behave very nearly like a perfect fluid when



FIG. 2.—Example of size and effect of boundary layer round wing section.

Grey shading indicates boundary layer; black area indicates effective wing shape; flow in perfect fluid round this shape is the same as flow of air round actual section.

it flows past well-shaped bodies or wings; the essential difference is that it does stick to the surface in a thin layer, which constantly increases in thickness from front to rear, and the presence of this layer, called the "boundary layer" does slightly modify the streamlines and therefore the pressures and suctions on the body; the result is that their components fore and aft do not exactly balance, and there is what is called a "form drag," but this is small compared with the skin friction. The thickness of this boundary layer varies with size and speed, and to give an example, the layer is about 1 inch thick at a point 6 feet behind the leading edge of a

wing travelling at 200 m.p.h. Inside the point 1 inch from the surface, the velocity begins to fall off, gradually at first, and then with increasing rapidity as the surface is approached.

The power required to drive the wing forwards through the air appears as energy continuously imparted to this boundary layer, or "wake" as it is called behind the wing. The kinetic energy of the wake can be quite easily measured, not only in the wind tunnel, but in flight, by a series of Pitot tubes, and much valuable information has recently been gained from these flight measurements, from which can be calculated the actual drag arising from that part of the wing immediately in front of the measuring apparatus.

In this way it has become possible to measure relatively easily and accurately not only such major effects as those of wing thickness, but also the differences produced by different degrees of smoothness of the surface, as, for example, the difference between a fabric surface and a highly polished cellulosed surface, or the effect of rivet-heads projecting slightly from a metal skin covering of the wing.

The accurate analysis of drag measurement, particularly on wings, is of the greatest value in throwing light on the difficult subject of "scale effect." It is obviously outside the scope of this article to give any full explanation of the phenomena encountered, but it may be said broadly that the behaviour of the boundary layer determines the drag, and at this stage we may examine the nature of the boundary layer rather more closely.

Considering for simplicity two-dimensional flow round a wing section, i.e. imagining all the movement of the air to take place in a vertical plane parallel to the direction of motion, there is one streamline which hits the wing near its nose, and a particle of air coming along this streamline is supposed to be brought to rest on the wing at a point called the "stagnation-point." Air in streamlines below this passes below the wing, and above this passes over the top surface. Now the particles of air actually touching the wing stick on to it; in other words, there is no slip over the wing surface. Immediately adjacent to this layer of stationary particles is a layer, or lamina, of slowly moving particles, and it is of course the shearing action between these adjacent layers which produces the tangential force on the wing surface which we call skin friction. Outside the slowly-moving lamina, there is another moving a little faster, and so on until the full speed of the stream is reached. There is, of course, no exact outer edge to the boundary layer, which sometimes is arbitrarily taken to include that part of the stream

which is moving at less than 99 per cent. of the free stream speed at the point considered.

If the above description of the boundary layer were complete, things would be relatively simple, but there are two regimes for the flow, with very different associated drags. Near the nose of the wing there is no mixing between adjacent laminae of air, each lamina sliding over its neighbour; this type of motion is stable, and is described as "laminar flow." The whole boundary layer increases in thickness as it travels back from the stagnation-point, but after travelling a certain distance, depending on speed, instability sets in and, except very close to the surface, particles of air from one layer find their way into another layer. When this lateral motion of particles is established, the boundary layer is said to be "turbulent," and a much higher drag is then found to exist, associated with much thicker boundary layer, and a high rate of shear in the very thin laminar "sub-layer." The point of change-over from laminar flow to turbulent flow is called the transition-point, and because the drag due to the turbulent flow is something like ten times as high as that due to the laminar flow, the exact position of the transition-point is of fundamental importance when studying the drag of a wing.

Relatively little is yet known as to what factors determine the position of the transition-point, and active research is in train to reach an understanding of these factors. One of the factors is the pressure gradient along the wing profile from front to back; if the shape of the wing is such that the suction on the top surface is falling rapidly as you go back from the leading edge, i.e. a positive pressure gradient, then the instability sets in earlier; Prandtl's experiments carried out some years ago illustrated this clearly, but all we can say now is that this in itself does not account for the observed changes in the position of the transition-point.

The steadiness of the air passing over the wing will have an influence on the position of the transition-point, and here we have an explanation of difference of drag which have been measured on one wing in various wind tunnels under what were believed until recently to be identical conditions. The air in a wind tunnel is maintained in motion by a propeller, and passed through honeycombs and guide blades to turn it round the corners of the tunnel; when passing through the testing section, the eddies produced by the propeller, etc., still persist to a small degree in the form of a general turbulence, that is motion which has not a perfectly constant velocity, or constant direction. Each wind tunnel has its own peculiar characteristics, and although these irregularities were

in the past considered so small as to produce a force on a body which, taken over a certain time, did give a true average, the effect on transition-point position, with its resultant effect on drag, has only recently been appreciated. Many hitherto unexplained discrepancies are now seen to arise from differences in turbulence not only between different wind tunnels, but between these and the full scale, when in the open air the turbulence which does exist is believed to be on too large a scale to affect the transition-point.

Thinking what might be done with this new knowledge, can we devise wing sections of lower drag by getting the transition-point to move further back from the leading edge? If the transition-point on the top surface could be persuaded to move back from its ordinary position of somewhere in the region of one-third of the chord measured back from the leading edge right to the trailing edge, allowing all the flow over the top of the wing to become laminar, the drag would be reduced by about half. On the bottom surface, the transition-point is quite near the leading edge, and if this could be brought right back, the drag would be reduced by another 40 per cent. Thus the total drag on a wing with laminar flow would be only about one-tenth of its present figure. Is there any way of achieving this, or is the presence of turbulent flow fundamental? Can the boundary layer be sucked away through holes in the surface right into the inside of the wing? Truly, a fascinating problem.

Coming back to the kind of improvements which are within easier reach, it is worth while considering for a moment the question of roughness of surface; how smooth must a surface be to achieve a minimum drag? As far as we know now, it is not possible to make the surface of a wing, or body, so smooth that the air will slip over it without sticking; as stated earlier, we do not know how to remove the stationary layer of air always clinging to the surface; as we leave the surface, the velocity gradient, together with the viscosity, produces the tangential force, or drag. In the region of turbulent flow, which as we have seen covers most of the wing surface, the velocity gradient in the viscous sub-layer is steep; on a wing travelling at, say, 200 m.p.h. the sub-layer several feet behind the leading edge is only about one-thousandth of an inch thick, and in this thousandth of an inch the velocity has risen from zero at the surface to about 100 m.p.h., which gives a very high rate of shear. Irregularities on the surface which do not project through the viscous sub-layer do not appear to have any adverse effect on drag; their disturbance of the flow is damped out, but once they begin to project into the turbulent boundary layer,

additional eddying is set up, with a consequent increase in drag. It will thus be clear that it is more important to keep the surface smooth where the boundary layer is thin, that is towards the leading edge.

It is at first sight rather surprising that the faster a wing is pushed through the air, the thinner is the boundary layer; it would seem the higher resistance at the higher speed would entail a larger wake. Actually, the width of the wake varies inversely as the speed, but of course the disturbance is much more violent; also the narrow wake fits in with a high rate of shear of the fluid near the surface, which produces the high resistance. It is clear, therefore, from this that it is more important to secure great smoothness of surface at high speeds; irregularities or lumps on the surface which would be wholly within the viscous sub-layer at low speeds will project through this layer into the faster-moving air at high speeds, and affect the resistance adversely.

Apart from what may be called the direct effect of roughness on drag, there is the indirect effect produced by roughness near the leading edge; if this is on that part of the wing where the flow is laminar, it may easily have the effect of promoting turbulence, in other words, bringing the transition-point forwards. An example recently given by Jones was observed during measurements of the transition-point on a wing in flight; a ridge only two-thousandths of an inch thick near the leading edge brought the transition-point several inches forward, with a consequential increase of drag of several per cent. This test was done at quite a moderate speed, and it shows how vitally important it is to get real smoothness near the leading edge for high-speed flying.

These great refinements of surface have only come into the picture as the aeroplane as a whole has approached a really streamline shape. A few years ago the open pilot's cockpit, the exposed undercarriage, and the engine cooling system might be likened to camels for resistance; what was the point of straining to eliminate any gnatlike roughnesses while the camels were there? With speeds going up to 250 and 300 m.p.h. the open cockpit automatically disappeared; the pilot was unable to attend to his duties in the draughts produced by such speeds. The undercarriages were for long a stumbling-block, but it was purely an exercise in mechanical engineering, though admittedly a very difficult one, to arrange for them to be retractable so that they could stow themselves away inside the fairing in flight, just as a seagull's legs are withdrawn under its feathers. The complication, the extra weight, and the slight degree of uncertainty as to whether the wheels would really

be down when you wanted to land all had to be faced ; but the result is that nowadays all high-speed aeroplanes have retractable undercarriages, in spite of all the drawbacks.

Turning now to engine cooling, we find here that not only has it been possible to reduce the drag to something very small, but theory has shown that it is quite possible to design a cooling system which actually has a negative drag, provided the speed is high enough.

There are, of course, two alternative systems of cooling an aero engine in flight ; the simplest is the air-cooling system in which heat is removed direct from the cylinders where it is generated by a flow of air passing through fins formed on the outside of the cylinders themselves. The other system is to surround the cylinders by a jacket containing water, which absorbs the heat, and is pumped away to a honeycomb radiator mounted in any convenient place on the aeroplane. The air-cooled cylinder normally runs hotter than a water-cooled one, and thus there is no real need to maintain a cylinder temperature below that of boiling water. As an alternative to water, a liquid with a higher boiling-point, such as ethylene glycol, has been successfully used ; another method is to allow the water round the cylinders to boil, and to carry the steam off and condense it in a honeycomb which looks exactly like a normal water radiator. The object of working at a higher temperature is that the radiator, or condenser, may then be smaller, and will consequently offer less resistance to the air.

Whichever method is used, a fundamental difficulty when contemplating high speeds is met, namely that while the cooling power of the fins or radiator goes up rather less rapidly than the speed, the resistance, or drag, goes up as the square of the speed. This was regarded by many people as one of the really serious obstacles to high speeds, which essentially call for large engine powers, that is, the dissipation of large quantities of heat by the cooling system.

In the last few years, however, what is known as " ducted cooling " has made its appearance, and the fundamental principles of this are well understood. It is clear from the above argument that it is economical to use air which is moving slowly ; more of it is required, but there is of course no shortage. In order to use slow-moving air, the engine, if air-cooling is used, or the radiator with liquid cooling, is installed in a duct consisting of both an inlet portion with the inlet mouth facing the relative wind, and an outlet portion with the exhaust orifice facing backwards. The air entering the inlet is slowed down, and its pressure rises ; the more of this slowing down which can be accomplished before the air

actually enters the mouth the better, as it is done without loss of energy due to duct-wall friction. Then the slow-moving air is passed over the cylinders or through the honeycomb and carries off the heat required. It is now speeded up through a contracting passage, the pressure falls as the velocity rises, and the air finally flows through the outlet orifice to join the main stream of air without shock. In the very high-speed aeroplanes which are now being designed, it is found possible to slow the air down as it passes through the honeycomb to quite a small fraction of the aeroplane's forward speed.

By slowing the air down, we see that it is possible to reduce the resistance to flow over the cylinders, or through the honeycomb, but some resistance is still encountered, and the walls of

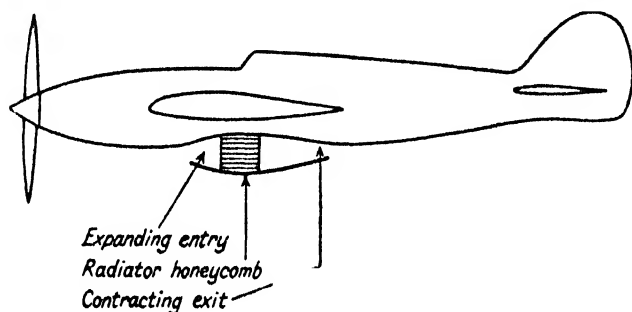


FIG. 3.—Section through ducted radiation system.

the duct are not without friction either. How then can we get negative drag?

The explanation is quite simple. The ducted cooling system is, if we look at it closely, in fact a heat engine. The entering air is first compressed as it is slowed down, heat is added at the point of high pressure, and the hot air is expanded; the cycle is that of an internal combustion engine, with the heat added at constant pressure. Of course the "compression ratio" of the cycle is very low; at 300 m.p.h. it is only about 1.1 : 1 as compared with, say, 5 : 1 in a normal petrol engine. Thus although the overall efficiency when considered as a heat engine is very low, there is at speeds in the region of 300 m.p.h. enough energy converted to balance approximately the friction losses in the whole system. It must be remembered that the total energy carried away per second by the cooling air is quite a large fraction of the useful output of the engine, and therefore a very low efficiency of conversion by the ducted cooling system will produce useful power comparable in size

with the losses due to the friction in the cooling system, which themselves represent but a small fraction of the total engine power.

As speeds go up, the regenerative effect will become greater, since the compression ratio increases nearly as the square of the speed; looked at another way, the cooling system may be said to act as a kind of jet propulsion, very inefficient as all jets are at low speed, but of increasing value as really high speeds are attained.

It is interesting to consider exactly how the propulsive force from this system is actually applied to the aeroplane. As explained above, the air is slowed up in the expanding duct as it enters the system with consequent rise of pressure; the forward components of this pressure on the inclined walls of the expanding duct provide a forward force. Although the opposite effect takes place after the heat has been added, the inclinations of the walls of the outlet part of the duct are less, and therefore the backward components of the pressures are less, because the contraction of the duct to produce an outlet speed equal to the inlet may be reduced on account of the heating of the air increasing its volume and thus its velocity.

We cannot leave a discussion of air resistance without a glance forward to the future. What obstacles must be overcome before we can fly at, say, one or two thousand miles an hour? Unfortunately there is something ahead of us over and above the normal increase of resistance according to the speed squared law. As we approach the speed of sound in air, some 700 m.p.h., we are forced to take account of the compressibility of the air, which at, say, half the speed of sound, is negligible. A very crude way of putting the fundamental difference between the air flow at present aeroplane speeds and supersonic speeds is to say that at low speeds, the wing (or body) can send out a message in front of it; the air some way ahead begins to move and prepares itself for the smooth passage of the wing; on the other hand, at supersonic speeds, no such message can be sent ahead of the wing, since the speed of sound is the maximum speed at which such a message can be sent; thus the air cannot prepare itself, and what is called a shock wave is set up as the wing travels along.

Just as the bow wave of a fast ship streams back and out from the bow, and continually breaks and dissipates its energy ultimately as heat, so the shock wave streams back from the nose of the wing at supersonic speed with continual dissipation of energy across its surface. The fundamental difference between a shock wave and a normal change of pressure is that in the latter we have adiabatic compression with the heat energy conserved, while behind the face

of a shock wave there is a sudden increase of pressure and temperature, and the layer in which this change takes place is so thin, being of the order of a thousandth of a millimetre, that heat is conducted across the boundary.

The result of this is that the rate of dissipation of energy, which is the same thing as saying the power required for propulsion, increases something like ten times or more when this shock wave is fully established.

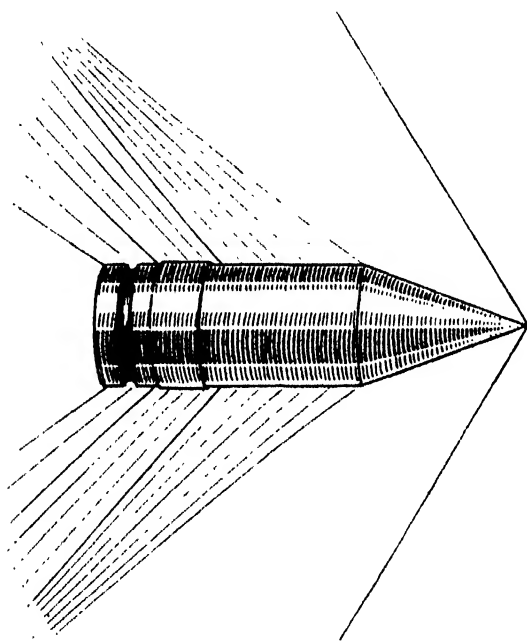


FIG. 4.—Shock waves produced by bullet at 1000 m.p.h.

It might be agreed at this stage that aeroplane speeds have a long way to go from the best at present, i.e. some 440 m.p.h., till we get to the speed of sound, but unfortunately shock waves are always set up before we are travelling as fast as sound. To appreciate this we must go back to the description given earlier of the pressure distribution over a streamline body, where we saw that there was a region of positive pressure over the nose, and suction over most of the middle of the body. Now increases of pressure are associated with lower velocities, and thus the air moving over the nose is travelling slower than the speed of flight; on the other hand, in the suction region, the local velocity is higher

than the speed of flight, and excess speeds of 30 per cent. over part of the surface of a wing are of normal occurrence.

Thus when we are flying at three-quarters of the speed of sound, say just over 500 m.p.h., the local velocity near the middle of a streamline body or wing may well be equal to that of sound, and a small shock wave will be formed at that point. In order to postpone the formation of this kind of wave, it is clear that we should try to use those streamline shapes which produce only small increases of local velocity. We have seen that the velocity changes are always linked up with pressure changes, and these in turn are linked up with the curvature of the streamlines. Thus we want shapes with small curvature, that is thin shapes, and experiments show that for high speeds thin shapes do in fact postpone the onset of the shock wave.

Thin shapes are bad from the structural point of view, particularly when we require the greatest possible rigidity, and difficult as it is at present to harmonise the conflicting requirements of design, ever-increasing difficulties confront the aeronautical engineer as he seeks for higher and higher speed.

An interesting example of an unexpected difficulty is found in the heating effect arising from the air friction over the surface of wing or body. At 100 m.p.h. the rise of surface temperature is only 1°C ., but the rise increases as the square of the speed, and at 700 m.p.h. it is 50°C . Although a certain rise may be advantageous, especially when flying high in a cold atmosphere, it would obviously be necessary to cool the occupants of a really high-speed aeroplane.

Shall we ever be able to reach the speed of sound, and fly even faster? There is no sign at present that with any power plant in sight, or with any improved structural materials in sight, we can hope to surmount this barrier, but when we look back, it is only just over thirty years since the Wright brothers managed to get their first power-driven aeroplane into the air at all. What did men say at that time of the probable speed of flight in 1938? The one scientific prophecy which is really dangerous is the negative one, and I think we should bear that in mind when we say that at the present time we cannot see any way of overcoming the enormously increased resistances generated by the formation of shock waves when approaching the speed of sound.

AGRICULTURAL RESEARCH AND HIGHER DEGREES

BY PROFESSOR R. G. STAPLEDON, C.B.E., M.A.

Director of the Welsh Plant Breeding Station, Aberystwyth

MODERN agricultural research covers an exceedingly wide field of endeavour; indeed there are but few of the sciences that may not have something to contribute to the solution of the problems that come under the purview of the worker in its sphere. The ultimate aim of agricultural research, by the very nature of the case, presumably is, or at least ought to be, to contribute directly to the welfare of mankind. This does not mean that agricultural research is necessarily debarred from adding to the sum of knowledge that constitutes the stock-in-trade of any particular science. The implied duty of the research worker in this field is, however, to seek for new knowledge in direct relationship to some urgent problem of agriculture; furthermore, it is both a necessary and a creditable endeavour for the worker to employ scientific and research methods with a view to ascertaining the best means of rendering already existing scientific knowledge of maximum utility in the interest of food production.

The amount of high-class and intricate research that must be undertaken with ultra-practical aims in view is probably far greater than is fully realized by either the research workers themselves or by those who administer research funds. This is realised far more fully by the farmer who, as a matter of fact, is always posing difficult conundrums to the scientist—conundrums, because of the soil and of agriculture, so difficult that it is seldom within the competency of a single specialist (the botanist, the chemist or the veterinarian) adequately to answer, or, in the majority of instances, to formulate a line of research most likely to lead to the correct and practical solution.

The difference between pure science and applied science is in essence this. The problems of applied science are always pre-defined and are pre-defined with a practical and in the last resort with a sociological, end in view. Ideally every problem which

engages the attention of the applied scientist should be one that because unsolved or insufficiently solved stands in the way of the betterment of the human race, stands in the way of mankind's health, happiness and purposefulness. The problems of pure science need not necessarily be pre-defined, and the worker in pure science is at liberty to follow any hare that crosses his path. He is deemed a good scientist so long only as he contributes to the sum of knowledge, and this in no matter how narrow a field. Not so the worthy applied scientist; he must adhere rigidly and undauntedly to his pre-defined problem. The applied scientist, in short, has a far more difficult rôle to fill than has the pure scientist, and of the two it is the former who needs to place himself under the greater self-discipline and who, as will transpire presently, needs to be capable of the greater self-effacement.

The problems of agriculture to a greater extent probably than of any other applied science are of an omnibus nature—in the sense that they are seldom within the province of any one department of science fully to solve. Every year that goes by tends further to emphasise this fact, and to render agriculture itself more involved. Thus to-day, perhaps as never before, the sociological importance of agriculture is coming to be realised, while it is being borne in on mankind that the nutritive properties of the products of the farm are of an importance at least as great as their general appearance and cheapness.

Two extraordinarily important facts follow from all this, both of which have a fundamental bearing upon the training of the men who are to become competent research workers in the agricultural field. In the first place almost more important than the actual solving of problems is the pre-determination of the problems which in fact it is desirable to solve. In the second place, since, as has been said, all the major problems of agriculture are "omnibus" in nature, it follows that only a team of workers representing many different branches of science, all working together in complete harmony and to a definite and pre-defined end, can possibly be competent to reach correct and practically useful solutions.

The agricultural research worker, therefore, needs to have very special attributes, and his training should at least be such as not to lead to the premature atrophy of such of these attributes as may lie latent within him. If his training as well as making of him a first-class technician and a first-class specialist can also accentuate these other essential attributes so much the better.

The truth is the successful agricultural research worker ("successful" as here pre-defined) needs to develop a certain sense and

feeling towards his subject ; for without that he will never be able properly and in detail to pre-define his problems. As well as the sense and feeling, however, he must have the technical equipment of the best pure scientist in the particular field that he wishes to make his own. More than all this, he must have that state of mind that makes it come natural to him to place all his cards on the table and to work gladly and enthusiastically as a member of a team.

This introductory discussion must be continued a little further before we can usefully come to grips with the explicit question of higher degrees. Experience would very definitely suggest that the sense and feeling for agriculture can only be attained, and if attained can only be retained, if the worker associates himself keenly with the field and/or with animals in the byre. The research worker whose particular line of study involves almost solely long hours in the laboratory should always be directly associated with a co-worker who is dealing with the implications of the laboratory findings in the field or in the yard. This association, if real and intimate, would be certain to have the effect of taking the laboratory man abroad on occasion, and all the time he would be refreshed and stimulated and kept to his pre-defined problem by the mere fact of being brought, if only indirectly, in touch with the living plant or the living animal. The will to keep in touch with one, or the other, or preferably with both and under as many conditions as possible, is a pre-essential to the make-up of the agricultural research worker.

The applied scientist is just as worthy of a higher degree as the pure scientist, and frequently more worthy, but although possibly the higher degree does not seriously interfere with the training or with the outlook of the pure scientist, to put it at its lowest there would at least appear to be a grave risk of its doing so in the case of the applied scientist.

We must now, however, examine the matter in more detail and with particular reference to the agricultural research man. We have to consider the case of the M.Sc., the Ph.D., and the D.Sc. In so far as training is concerned, the D.Sc., is not under question, and those who understand academic matters are aware of the attainments as well as of the status that this degree invariably implies, but because of its status it does not necessarily follow, however, that even the D.Sc., as a degree, is beyond reproach in its influence on research in general, and on agricultural research in particular. We shall again allude to the D.Sc., when in the closing paragraphs of this article we revert to general considerations.

Apart from the question of training, and apart from agriculture

as such, there are certain serious criticisms to be levelled against both the M.Sc., and the Ph.D.

At most universities the M.Sc. can be variously obtained, and therefore the degree as such does not imply any particular standard of attainment, nor does the holding of this degree necessarily mean that the recipient has undergone any rigorous and supervised training in research. The presentation of a thesis is the one absolute desideratum. Such a thesis may, however, be presented by a young man who returns to College immediately after graduating, and who undertakes a limited piece of research under supervision for the explicit purpose. Perhaps most generally theses for the M.Sc. are presented by men who already hold posts in a teaching or research department. The standard of excellence is then sometimes exceedingly high, and the candidate is likely to have had actual research experience and in many cases a long acquaintance with research technique.

Now if the candidate for the M.Sc. is on the staff of a research department, or institution, he should almost of necessity have been engaged upon team-work, and therefore, and almost of necessity, the individual work entailed in amassing the data for a thesis which needs must be presented under sole authorship is not compatible with the highest ideals of the team spirit. Consequently, and by that much, the M.Sc. degree is not in keeping with the aims and needs of modern research. It may possibly be in keeping with modern teaching requirements, but that is another matter and is not here under consideration.

The Ph.D. unlike the M.Sc. is intended only for post-graduate research students, that is to say, for men who pass straight on from graduating to undertake a prescribed piece of research under supervision with a view to presenting a thesis for their doctorate. Members of staff of the universities are usually debarred from offering themselves as candidates for the Ph.D. It follows, necessarily, from this state of affairs, that on the score of attainment, and speaking quite generally, the Ph.D. cannot be regarded in fairness and in fact as necessarily a higher degree than the M.Sc. The whole position is a confused one, for in the popular view "Doctor" does imply a very definite status, something at least as much higher than Master, as Master is deemed to be higher than Bachelor. The confusion is rendered the more complete since M.Sc. may mean much or little. The real trouble is that Doctor has a definitely higher post-obtaining value than Master: this is patently so in the commercial world and such is the immense psychological significance of a word that in cold fact it is probably

also true in the research and academic worlds. Thus a position has arisen which is not only ridiculous but grossly unfair.

As matters stand at present all that can be said for the Ph.D. in comparison with the M.Sc. is that the former degree is at least more or less standardised, and that the recipient of the degree will necessarily have had some research training under supervision. The Ph.D. degree, incidentally, serves within certain limits to date a man, but it is to be feared that this dating, which in any event becomes less apparent in relation to the M.Sc. as the former degree becomes longer established, is not sufficient in the eyes of the uninitiated to mark the profound difference between the D.Sc. and Ph.D. as a qualification—the holder of either degree is a doctor !

This confused position as to university degrees, and as to their correct evaluation, is to-day, and particularly in relation to the applied sciences, a matter of grave national concern. Industry, including the agricultural industry, every year employs more and more scientific men, and industry cannot be expected, and should not be expected, to understand all these academic subtleties, but the managing director, or the establishment officer, who does not understand them is at a disadvantage when considering candidates, and especially when interviewing candidates. He will be in the position of being easily misled unless he can ask a number of searching questions about the degree or degrees which each of the several candidates hold.

It is difficult indeed to find any justification for the granting of two degrees so closely parallel as the Ph.D. and the M.Sc. and thus, purely on broad academic grounds, there is a strong case to be made for discontinuance of the Ph.D. degree. This case would be greatly strengthened if it were to be shown that the training which a man receives for the degree were necessarily uneven as between subject and subject, and university and university, and still further strengthened if it were shown that in certain subjects because either of the nature of the subject or of the regulations that are operative it was virtually impossible properly to train men who are candidates for the degree.

No matter what the subject, there is always the supervisor, and thus the quality of the training, of the research, and of the thesis itself, is necessarily as much a function of the supervisor as of the candidate, and both at the end are in effect under examination. Therefore, it stands to reason that the training and the assistance candidates receive cannot help but vary over the widest margin as between subject and subject, university and university.

In the case of general examinations by subjects this exaggerated

duality between student and teacher does not occur, and in any event as far as different departments and groups of subjects are concerned the influence of a certain necessary duality more or less cancels out, and the student reveals himself in his examination papers as a distinct entity.

We now come to the crucial matter of training, for if the Ph.D. is intended to signify anything of real importance it is that the holder of the degree is by training, and by virtue of the technique and point of view he has acquired, fully qualified to conduct research in the subject in which he has specialised. We will confine attention to agriculture, and in order to be explicit and it is hoped authoritative as far as we go, we shall further confine ourselves to field husbandry and to that branch of field husbandry which has to do with grassland.

The period allowed for preparation for the Ph.D. is usually two sessions, and even if this period is extended to two full years it does not give enough time for the conduct of a piece of research sufficiently widely based adequately to train a man in the research methods applicable to subjects as wide and as involved as the typical agricultural subjects we are considering. The method of approach to such subjects is necessarily determined by the growing seasons, and the technique to be adopted is in the main a field, a greenhouse and an out-of-door technique, and one that can only be employed and practised during a part of the year. This is not all, the amount of data that need to be collected relative to grassland problems is enormous, and therefore in dealing with any problem sufficiently wide to afford a proper training, and to develop the candidate's point of view collaboration between several candidates would almost invariably be necessary. But even if such collaboration were encouraged by the acceptance of dual authorship theses for the degree, there would still remain the insurmountable limitation set by but two growing seasons. Above all this we have constantly to remember that by his very terms of reference the man in this field is committed, as we have explained, to a worth-while practical problem, and therefore of necessity to an involved problem, and his training, if it is to be of any use at all, should render him capable of dealing with widely based problems. Narrowness and restrictedness are to be avoided at all costs. An important part of the training, therefore, is the development of that sense which leads to the quick realisation of the kind of problem that is capable of yielding important practical results, and therefore of the kind of material and methods that can alone lead to the necessary solutions. This sense can only be developed by the handling of a great deal of material. The breeding of herbage grasses by genetical methods

affords an excellent example. The worker in this field needs not only to handle very large numbers of single plants (a mass of genetical material) but also to conduct large numbers of complicated field trials, or to be associated with another man in the conduct of such trials. In the actual genetical work the necessary first start is always self pollinations. It will take one year to obtain the progeny of these selfings. The trainee is likely to obtain segregation in some of his material and he decides he will study the inheritance of some particular character. He must out-cross or in-breed the next season. At the best, and with good fortune, he might by these methods obtain some definite results *after three seasons*. But to have followed a problem that could have been thus comparatively easily dealt with would have been too simple and too restricted as a training. No training in the genetics of cross-fertile herbage plants could be regarded as adequate until the man has had experience in the study of some one character in relation to at least one other character, and this would involve out-crossing with subsequent in-breeding, and the accumulation of an amount of material that would be much greater than is easily realised. In principle the same type of disabilities would present themselves in relation to research conducted on any general grassland problem.

All this means in effect that the only possible way to deal with a Ph.D. candidate in these subjects is to put him on to some minute and restricted fragment of a worth-while problem, or to make over to him a mass of existing material that is being studied by a senior man, or by a group of men at the particular department. It is not often possible to adopt this latter plan, even if the trainee is an exceptionally good man, and therefore the number of candidates that could be dealt with properly at any particular institution would be too restricted to be of much account.

Besides this, the making over of material does restrict the scope of the training that can be given and from the thesis point of view it necessarily means that the supervisor will have contributed the giant's share to the worth-while and practical results of the research in question, and also a too large share to the general character of the thesis.

Apart from the time factor a solution to the whole difficulty is not to be found in extending the training period to five years. Five years would be sufficient to allow of one get-ready year in which the candidate would collect his material, lay down his plots and become generally conversant with the broad lines of the technique which he would have to use, and four data-amassing years. To adopt such a period and such a plan would, however, place too

heavy a burden on the research departments, for it would make extraordinarily heavy calls on greenhouse and ground space, and on all grades of the staff. The expense involved would be greater than could possibly be collected in terms of student fees. *

As matters stand it is practically impossible, with a clear conscience, to accept candidates for the Ph.D. as trainees in the larger of the out-of-door subjects. This is of itself a very serious matter, for it means that such candidates are driven to take up and look for lesser and much more restricted subjects, and generally speaking laboratory subjects at that, in which to obtain their research training in field husbandry. The accumulative influence of this on agriculture, which is essentially and above all an out-door and a widely based science, can only be retrograde.

The irony of the whole position arises from the fact that it is easy to give an excellent research training in two years to a man interested in grassland problems, and including genetical problems, who seeks only training and is not hampered by the restriction implied in the ultimate preparation of a thesis for a degree. Such men can be passed from department to department, and make themselves fully acquainted with the whole of the technique involved, and with the broad inter-relations between the laboratory, the greenhouse, small field plots, large field plots and farm practice.

At the Welsh Plant Breeding Station we have had men coming to us for training, some of whom have had the millstone of a thesis (M.Sc. or Ph.D.) firmly fastened around their necks, and some of whom have been free agents—trainees pure and simple. The men who have taken most away with them in spirit, outlook and in technique have undoubtedly been the free agents. The conclusion to be drawn from what we have said is undeniably that the Ph.D. serves as a definite handicap to the evolution of men of the right calibre to conduct far-reaching research in one of the most important branches of the science of human welfare. Men are being driven towards the easier and the narrower, instead of towards the broader and the more difficult, and the suspicion will intrude itself that the effect is the same in other branches of applied science for the general influence is to encourage men to specialise too soon as well as too narrowly.

It would be too much to say that the day of the individual specialist is over, but science has grown so vast and all-embracing that to an ever-increasing extent the need for well co-ordinated team-work is everywhere apparent.

Team-work is chiefly necessary where science is advisedly employed in the service of man, and applied science is now of necessity

intruding itself upon man's every activity. All this has to be accepted, and accepted first and foremost by the universities, for the universities are responsible for the training, and to a very real extent for the outlook, of the scientists of the future. As a matter of fact the wholesale granting of higher degrees on a thesis, which amounts to an examination, basis has in any event been a retrograde action. A university should be a place that recognises as little distinction as possible between man and man, and which aims at as little standardisation as possible. A place where staff and students, the elect and the more ordinary, work shoulder to shoulder only for the advancement of knowledge and the betterment of mankind. The granting of higher degrees has been in keeping with modern tendencies alas ! for we live in an almost incredibly personal age, an age in which every individual to at least some extent and by some insidious process is driven towards the lime-light, and an age in which the press seem only able to discuss and to describe every daily happening in terms primarily of some individual or another. A doctor amongst the ordinary undoubtedly, and unfortunately, has a better publicity value than a minister, and therefore has also a better propaganda value, and universities to-day are not innocent of propaganda ; it is essential to their well being, so they consider, to court a full share of publicity, and to accumulate a large number of students. It is a sad commentary on human nature and on modern tendencies if post-graduates have to be enticed to remain on at the universities by the granting of high-sounding higher degrees, and it is sadder still if because of these higher degrees the training given to research students cannot be as good as it could otherwise be, and saddest of all, if the training does not imbue the rising generation of scientists with the team spirit and with an intense realisation of the immensity of the problems that await solutions.

To put it quite blatantly, by our present methods, overshadowed as they are by the degree system, we are tending to train men to conduct research in the buds, twigs, and in some of the smaller branches of agricultural science, rather than in AGRICULTURE : a criticism which in the same general terms we believe could be levelled, with equal justice, against the training for almost every major applied science. A system to meet modern needs should assuredly produce specialists in each applied science as such, as well as in its every branch and sub-branch, and to-day the most urgent need is for the former type of specialist.

The agricultural scientist cannot be separated in treatment from other applied scientists, and the applied scientists cannot in equity be separated from the pure scientist, but it would probably be better

for all if higher degrees granted on the thesis basis were completely abolished. The Ph.D. has served no really useful national purpose, and has carried with it innumerable psychological effects which have done neither the young doctors nor the universities any good, and should assuredly be abolished root and branch. The M.Sc. is perhaps more innocent, despite the fact that it stands for too wide a range of attainment and qualification, and of research training. Because many of the candidates for the M.Sc. already hold research positions if this degree is to be retained the submission of papers or theses of joint-authorship should be considered as a merit and be definitely encouraged instead of being disallowed, for ability to collaborate is one of the outstanding necessities of the modern scientist.

The D.Sc. stands in a different category, because it does not influence a man's training. It may, however, influence a man's attitude towards team-work and collaboration, and may so influence his attitude over a long run of years, during which time he is himself in a senior and influential position, and therefore capable of considerable psychological mischief to the man himself, and therefore also of considerable mischief to the spirit that should animate a research institution.

It would perhaps be going too far to advocate the abolition of the D.Sc. degree because of these possibilities, possibilities which are increasingly menacing, however, in view of the ever-increasing development of research departments and institutions working on wide terms of reference demanding intimate collaboration between large numbers of workers. The case of D.Sc. would probably be best met if the submission of joint papers were always regarded as of itself striking evidence of the candidate's suitability for the status implied by the conferring of the degree.

In conclusion it may be suggested that the only justifiable *raison d'être* for granting degrees is firstly to inspire students to work and to undergo a rigorous training in technique and to encourage qualified men in positions to hold unremittingly to their researches in a spirit in sympathy with the ever widening range of science : and secondly, to assist the university authorities and those who have posts to fill to put the right men in the right positions. If the degree system on the one hand tends to interfere with the giving of the best possible training in a reasonable length of time, and on the other does not sufficiently accurately or sufficiently clearly categorise the men who pass through the universities, then the whole system falls to the ground. The system has had a fairly long trial. It is certainly growing more complicated, and this very fact probably clearly indicates that the system is failing but that nobody likes to admit it.

CO-ORDINATION COMPOUNDS

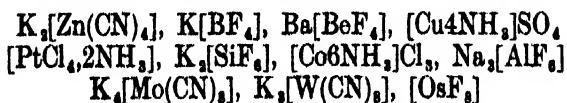
By E. G. COX, D.Sc., F.Inst.P.

The University of Birmingham

AND W. WARDLAW, D.Sc., F.I.C.

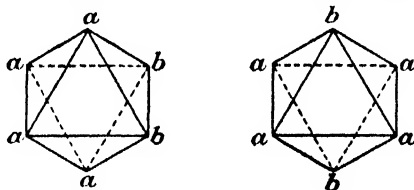
Professor of Physical Chemistry in the University of London, Birkbeck College

WERNER'S theory of co-ordination, which was first put forward in 1891, aimed at explaining the structure of that puzzling range of chemical compounds which chemists at that time conveniently shelved under the name of molecular compounds. They were formed by the combination of apparently saturated molecules and their structure appeared to be quite independent of the ordinary valency rules. Werner proposed for them a theory of molecular structure founded on entirely new principles. He pointed out that the structure was usually determined by the tendency of a central atom to attach to itself 4 or 6 or 8 atoms or groups, and that, for example, the molecular compounds $\text{PtCl}_4 \cdot 2\text{KCl}$ and $\text{PtCl}_6 \cdot 2\text{KCl}$ were actually the co-ordination compounds $\text{K}_2[\text{PtCl}_4]$ and $\text{K}_2[\text{PtCl}_6]$, where the square brackets enclose the co-ordination complex. He considered that the four or six chlorine atoms, immediately surrounding the platinum atom, formed with it a stable complex outside which were the ionised potassium atoms. In other cases, such as $[\text{PtCl}_4 \cdot 2\text{NH}_3]$ the complex is not an ion, so that there are no units outside "the inner or first co-ordination sphere." In $[\text{PtCl}_4 \cdot 2\text{NH}_3]$ and $\text{K}_2[\text{PtCl}_4]$ the platinum has a principal valency of two and a co-ordination number or covalency (to use the modern term) of four, whereas in $\text{K}_2[\text{PtCl}_6]$ the principal valency is four and the covalency six. Examples of atoms showing covalencies of 4, 6 or 8 are seen in the following compounds:



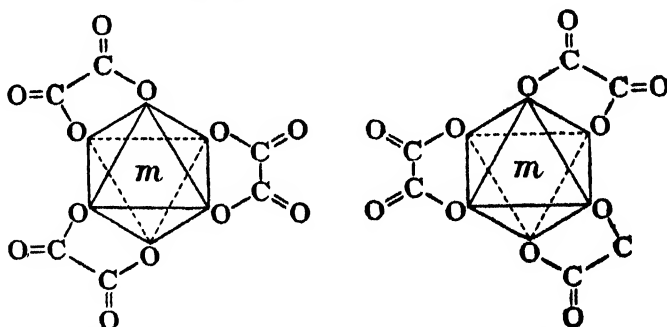
As an extension of his theory Werner determined the number of isomers which could be prepared of co-ordination compounds of different types. In the case of co-ordination compounds exhibiting a covalency of six, three possible spatial arrangements of the six

units suggest themselves : the hexagon, the triangular prism and the octahedron, each of which has six points equidistant from its centre. If the six units round the central atom are distributed in the form of a hexagon or triangular prism then *three* isomers are possible in compounds of the type $[Ma_4b_2]$ whereas actually in the numerous cases investigated only *two* isomers are ever found. The existence of two isomers of this type is exactly in accordance with an octahedral configuration as the following diagram shows :



This octahedral type of configuration was supported by Werner's discovery that many co-ordination compounds similar to the well-known potassium chromi-oxalate $K_3[Cr(C_2O_4)_3]$ could be resolved into optically active forms. That such compounds could exhibit optical activity had never been suspected, but that they should do so immediately became apparent on the theory of an octahedral structure.

In the following diagram it is seen that the complex ion $[Cr(C_2O_4)_3]^{3-}$ can exist theoretically in forms which are related as object and mirror image. Each oxalate group occupies two positions in the octahedron (such groups are designated "chelate groups" by G. T. Morgan).



The optical activity thus predicted has been realised in numerous compounds in which the central atom shows a covalency of six, and affords a striking vindication of Werner's views. For example, optical activity has been demonstrated in co-ordination compounds of no less than eight metals of the transition periods, *viz.* Cr, Fe, Co, Ni, Ru, Rh, Ir, Pt. X-ray analysis and electron-diffraction

have shown that the octahedral configuration is widespread in minerals and chemical compounds and it appears to be the usual distribution when a central atom has a covalency of six. One of the few exceptions to this is molybdenite, MoS_2 , in which each molybdenum atom is surrounded by six sulphur atoms in the form of a triangular prism.

It is now generally accepted that there are two fundamentally different kinds of linkage which are designated as ionised and non-ionised, electrovalent and covalent. An ionised link, which has no directive properties in general, occurs when one electron is transferred from one atom to another, as in sodium chloride. A covalent link, on the other hand, results from the sharing of two electrons between two atoms, each of which contributes one of the electrons. The existence of chlorine in the ionic and non-ionic forms is seen in the well-known co-ordination compound $[\text{CoCl}_5\text{NH}_3]\text{Cl}_2$, and it will be realised that whenever an element forms part of the co-ordination complex it is bound to the central atom by a non-ionic link. It is not necessary, however, for such a link to be a covalency as defined above. Thus, it is well known that in the H_2O or NH_3 molecule there is a "lone-pair" of electrons which can form a link if another atom can be found to share them without itself contributing any of its own electrons in return. This third type of link can be conveniently described as a co-ordinate link and may be written, following Sidgwick's suggestion, as an arrow $\text{A} \rightarrow \text{B}$, pointing away from the atom which contributes the two electrons to the link.

Whilst the octahedral configuration appears to be general with 6-covalent atoms there is no such universality in the case of 4-covalent atoms. By analogy with carbon it might be inferred that whenever four units surround a central atom the configuration will be tetrahedral. Nevertheless, the possibility cannot be ignored that, when two of the six co-ordination positions are vacant, the remaining four may form a square rather than a tetrahedron. Werner maintained that the tetrahedral configuration was not general and that in the cases of the ammines of platinum and palladous chlorides, $\text{PtCl}_2 \cdot 2\text{NH}_3$ and $\text{PdCl}_2 \cdot 2\text{NH}_3$, the structure was planar. In such compounds, if the four units are arranged in a plane about the bivalent atom, two isomeric derivatives, a *cis* and a *trans*, should exist



Actually a considerable number of simple compounds of 4-covalent platinum were known to exist in two distinct modifications and gave support to Werner's view.

Between 1899 and 1926 it was clearly demonstrated by a series of important investigations, using the classical methods of organic chemistry, that a wide range of elements, *viz.* tin, sulphur, selenium, nitrogen, beryllium, copper and zinc, could have tetrahedral arrangements for their four valencies. On the other hand, during this period, the only support for Werner's view was the isolation by Vernon [10] in 1920 of two isomeric series of compounds of the type $\text{Te}(\text{CH}_3)_2\text{I}_2$ that gave the same values for their molecular weights. In view of this equality of molecular weights Vernon supposed that they represented the *cis* and *trans* forms of molecules having a planar configuration similar to that which Werner had assigned to the isomeric platinumous compounds of the type $\text{PtCl}_2 \cdot 2\text{NH}_3$, thus :

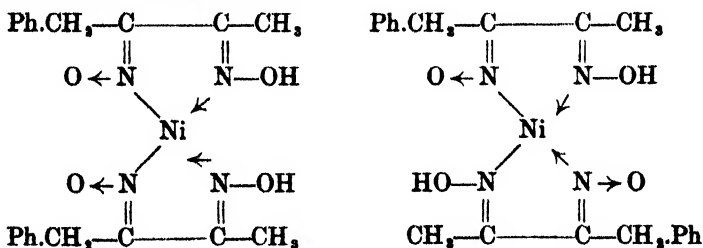


In 1929, however, considerable doubt was thrown on this evidence for the planar structure of tellurium by Drew [11], for he proved that whilst one form had the composition $\text{Te}(\text{CH}_3)_2\text{I}_2$, the other modification was a polymer of salt-like character with the structure $[\text{Te}(\text{CH}_3)_2][\text{TeCH}_2\text{I}_2]$. This abrupt disappearance of the only evidence for a planar configuration, outside the cases of palladium and platinum, rendered the behaviour of these two metals the more remarkable and called for further work of a decisive character to establish whether planar structures for 4-covalent compounds could, in fact, exist. Although the chemical support for Werner's views was slight some physical evidence had accumulated which gave strong support. An X-ray investigation in 1922 by Dickinson [12] had indicated that in the complex ions $[\text{PdCl}_4]^{--}$ and $[\text{PtCl}_4]^{--}$ the metal atom lay in the same plane with the four chlorines. Further, in 1931, Pauling [13] gave reasons, based on wave mechanics, for concluding that a planar structure was possible, not only in the cases of 4-covalent palladium and platinum but also with nickel. In recent years therefore this question of the spatial distribution of the valencies of 4-covalent atoms has aroused unusual interest and inspired a vast range of researches.

It is evident that there must be a theoretical explanation why in certain cases the structure is tetrahedral and in others planar.

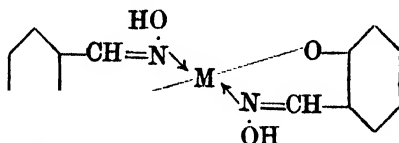
Pauling's theory attempts to give this explanation. It is generally known that the electrons in an octet are divided into two levels of 2 and 6 and those of an 18 group into three levels of 2, 6 and 10. The spectroscopic designations for these levels are *s*, *p* and *d*. Thus only *s* and *p* levels occur in an octet while in a shell of eighteen electrons *d* levels are also possible. Starting from the usual idea that a bond involves the sharing of two electrons Pauling predicts that when four bonds are formed by means of *s* and *p* electrons only, their distribution is tetrahedral. When, however, *d* electrons are used and the linkage is of the type sp^2d an arrangement of four bonds at 90° in one plane is predicted. The latter possibility arises particularly with elements of the transition periods. Moreover, as Pauling points out, since the *d* electrons are chiefly responsible for the magnetic moment of the atom, sharing of them should reduce this moment (since a postulate of the theory is that the two electrons in a bond have opposite spins) so that, for example, bivalent nickel which is paramagnetic in its simple salts should be diamagnetic in any of its 4-covalent compounds of planar structure.

Werner had already expressed the view that bivalent palladium and platinum could give 4-covalent compounds of planar type, but that nickel could function in this way was an entirely new suggestion. It was with particular interest therefore that the announcement was received in 1932 that S. Sugden [14] had isolated two isomeric forms of the nickelous derivative of the unsymmetrical oxime, benzyl-methylglyoxime, with melting-points of 168° and $75-77^\circ$ respectively. These compounds proved to be diamagnetic, as were also the nickel derivatives of dimethylglyoxime and diphenylglyoxime, a fact of special interest from the point of view of Pauling's theory. With a tetrahedral configuration for the nickel bonds the two forms would be related as object and mirror image and would be, presumably, paramagnetic.



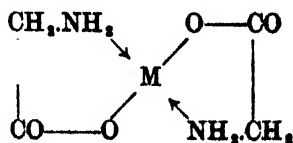
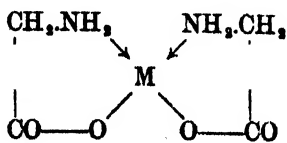
With the object of proving conclusively that 4-covalent nickel may be planar and diamagnetic, the salicylaldoxime derivatives of platinum, palladium, and nickel were investigated by Cox, Pinkard, Wardlaw and Webster [15]. The nickel compound is well known

in quantitative analysis and the palladium derivative has been suggested for the microchemical estimation of this metal. Two molecules of salicylaldoxime can be attached to these bivalent metals, each molecule of oxime contributing one principal valency and one co-ordinate link.

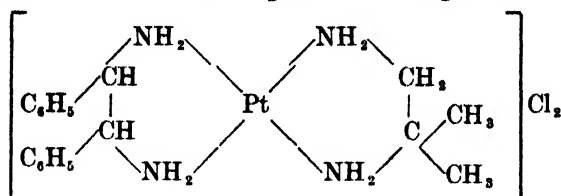


All the compounds $M(C_7H_7O_2N)_2$, where $M = Ni, Pd, Pt$, crystallise well without solvent of crystallisation; they are almost insoluble in water but soluble in carbon tetrachloride, chloroform and benzene. Molecular weight determinations prove them to be monomeric and undoubtedly their properties indicate that they are covalent structures. The nickel and palladium compounds form isomorphous crystals and an X-ray examination showed that the molecule in each case possessed a centre of symmetry and therefore had a planar trans-configuration. The platinum derivative occurred in two modifications, one of which had definitely a planar trans-structure. The 4-covalent nickel compound was obviously an excellent case with which to test the validity of Pauling's theory, for it had been shown to be planar and should therefore be diamagnetic. The magnetism was determined and found to agree with Pauling's views.

The changed position with regard to the stereochemistry of 4-covalent atoms was admirably dealt with by S. Sugden [16] in a discussion on stereochemistry held by the Chemical Society in London in 1936. He emphasised that there was definite evidence for the frequent occurrence of planar configurations not only amongst 4-covalent compounds of nickel, palladium and platinum but also of copper. Sugden pointed out that there were three main lines of evidence which favoured a planar distribution of valencies for 4-covalent nickel, palladium and platinum. First, there was the occurrence of *cis* and *trans* isomerides when two unsymmetrical chelate groups are attached to the metallic atom. As examples of this there are the isomeric nickel derivatives of benzyl-methylglyoxime, previously mentioned in this article, and the glycine derivatives of palladium [17] and platinum [18] of the types shown below :



Secondly, there is the evidence from optical activity provided by the resolution of the 4-covalent platinum compound



by Mills and Quibell [19] in 1935. If the valencies of the platinum be in a plane (Fig. 1), the compound has no plane of symmetry and must

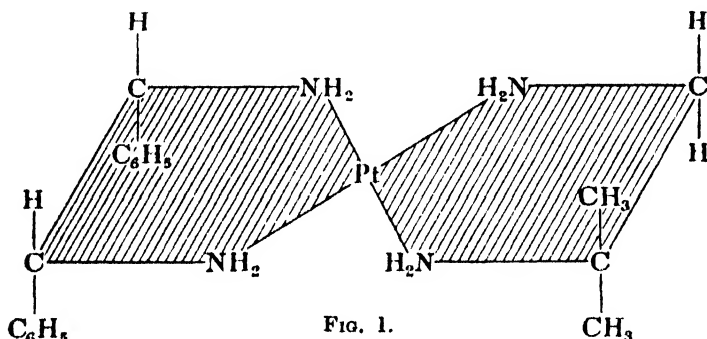


FIG. 1.

be optically active. On the other hand, if the valencies of the metal atom have a tetrahedral disposition (Fig. 2) then the planes of the

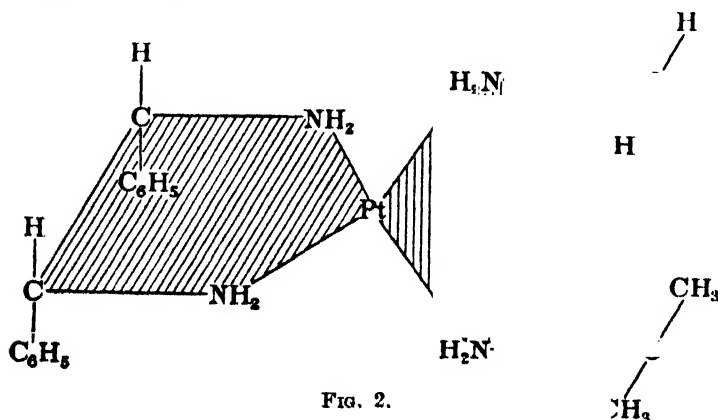
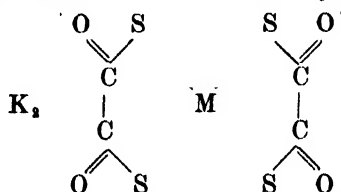


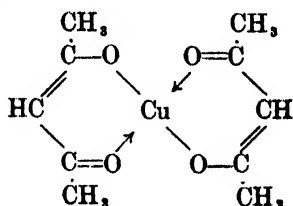
FIG. 2.

two rings will be at right angles and the molecule possess a plane of symmetry and will not be resolvable. Actually the compound was resolved into optical isomers of high stability. Finally, there are X-ray studies by Cox, Wardlaw [20, 21] and others which have demonstrated a planar configuration in no less than 14 derivatives

of nickel, palladium and platinum. A striking example of this planar configuration is in the dithio-oxalates. The anhydrous potassium nickelo-dithio-oxalate is completely isomorphous with the corresponding palladium and platinum derivatives and the good scattering power of the sulphur atoms enabled the position of all the atoms in the molecule to be determined by X-ray analysis [21].

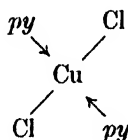


The extension of these planar structures to bivalent copper was of special interest, for Mills and Gott [22] in 1926 had recorded that 4-covalent copper in its benzoylpyruvic acid derivative gave rise to optical activity and so appeared to have a tetrahedral valency distribution. Nevertheless, in 1934, an X-ray examination of $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ [23] had shown that four of the water molecules had a planar arrangement round the copper atom and this result suggested that if suitable 4-co-ordinated compounds were examined, a planar structure would be found. Cox and Webster [24] therefore examined a number of copper derivatives of β -diketones such as the cupric salt of acetylacetonate and found a planar arrangement for the copper valencies.



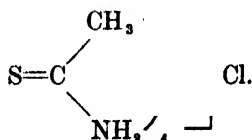
It may perhaps be of interest to indicate how it was possible to arrive at this conclusion without the necessity of an exhaustive analysis by X-rays of these somewhat complicated molecules. In some cases, space-group considerations showed that the molecule possessed a centre of symmetry; this immediately demonstrated its planar-trans character. In others the smallest cell-dimension excluded a tetrahedral configuration. It is well established that the distance apart of carbon atoms in neighbouring molecules of crystalline organic compounds is approximately 3.7 Å. From this value, a simple calculation shows that if the disposition of the Cu—O bonds in the crystal of copper acetylacetonate were tetrahedral, the distance apart of copper atoms in neighbouring molecules

would probably be about 5.3Å. and certainly not less than 4.8Å. On the other hand, with a planar distribution of valencies the distance apart of copper atoms in neighbouring molecules might be anything from about 3.7Å. upwards according to the arrangement of the molecules. Actually for each of the four diketone compounds examined by Cox and Webster, one of the cell dimensions (which must be the distance apart of copper atoms in different molecules) was less than 4.8Å. The planar configuration for 4-covalent cupric compounds is now fully confirmed by a range of experimental data. J. M. Robertson [25] found that the phthalocyanine derivatives of nickel, platinum and copper had the metal atom and the four surrounding nitrogen atoms in one plane. D. Harker [26] in 1936 investigated the crystal structure of the dihydrate of cupric chloride $\text{CuCl}_2 \cdot 2\text{H}_2\text{O}$ and concluded that each copper atom is attached to two chlorine and two oxygen atoms by covalent linkings directed to the corners of a square. Further, Cox, Sharratt, Wardlaw and Webster [27] found that $\text{CuCl}_2 \cdot 2py$ (where py = pyridine, $\text{C}_5\text{H}_5\text{N}$) had a planar-trans structure



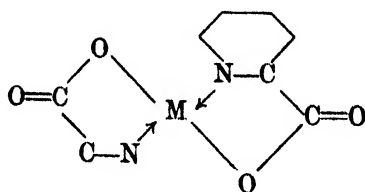
The work which has just been surveyed shows that many 4-covalent complexes of copper, nickel, palladium and platinum actually possess a planar configuration and that this configuration is maintained even when considerable changes are made in the nature of the co-ordinated groups. On the other hand, recent investigations have demonstrated quite clearly that a change in the *principal* valency of a 4-covalent atom may influence the spatial distribution of the bonds. For example, an X-ray study of trimethyl-platinic chloride, $\text{Pt}(\text{CH}_3)_3\text{Cl}$ [28], in which the platinum is 4-covalent but quadrivalent, has disclosed that the platinum valencies are not in a plane with the metal atom and are, presumably, tetrahedrally distributed. Again, nickel carbonyl, $\text{Ni}(\text{CO})_4$ [29], in which the nickel has zero principal valency, has been investigated by electron-diffraction methods and proved to possess a tetrahedral structure. Striking examples of this change of structure with change in the principal valency of the central 4-covalent atom have also been found in some very recent investigations of co-ordination compounds of copper, silver and gold. Prior to 1936, the only data on the configuration of 4-covalent argentous derivatives was that of Hein and Regler [30] who, in a preliminary

note, stated that they had effected a partial resolution of the silver derivative of that well-known compound, 8-hydroxyquinoline. Later, they described their work in detail [31] and stated that by the use of the bromocamphor-sulphonate they had obtained evidence that the silver compound was optically active, although the activity could not be retained when the optically-active acid was removed. They concluded that the 4-covalent silver atom must have a tetrahedral disposition for its valency bonds. Cox, Wardlaw and Webster [32] then examined by X-ray methods the substances formed by the co-ordination of four molecules of thioacetamide with cuprous and silver chloride respectively

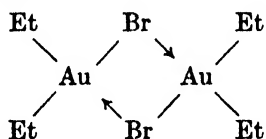


They also examined the complex cyanide of cuprous copper, $\text{K}_3[\text{Cu}(\text{CN})_4]$. In each of these substances a tetrahedral distribution was found for the four links with the copper or silver atom. It is interesting to notice that in all these compounds, the co-ordinated metal atom is associated with a number of electrons which represents the atomic number of an inert gas. For example, the effective atomic number, as Sidgwick calls it, of the copper atom in $\text{K}_3\text{Cu}(\text{CN})_4$ is $29 + 3 + 4$, i.e. 36, the atomic number of krypton. It is also noteworthy that the complex ion $[\text{Cu}(\text{CN})_4]^{3-}$ has exactly the same number of electrons and presumably the same electronic distribution as the neutral molecule $\text{Ni}(\text{CO})_4$ which has also been shown to be tetrahedral. Mann, Purdie and Wells [33] also find a tetrahedral distribution of valencies for the copper atom present in the co-ordinated cuprous complex, $[\text{Et}_3\text{As} \rightarrow \text{CuI}]_4$.

Now whilst univalent copper and univalent silver form 4-covalent compounds of tetrahedral type it has been demonstrated that bivalent silver, like bivalent copper, is capable of giving 4-covalent complexes of plane configuration. This statement is based on the fact that argentic picolinate has been shown to be isomorphous [34] with cupric picolinate, which X-ray methods prove to have the trans-planar structure



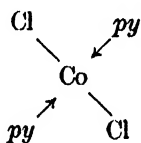
Argentate picolinate therefore has a similar structure and has moreover the high birefringence that would be associated with such a molecule of trans-planar type. By analogy with copper and silver one would expect that univalent gold in its 4-covalent compounds would be tetrahedral. At present there are no data on this matter. The configuration of complexes containing 4-covalent gold in its higher valency of three is now, however, well established. Cox and Webster [35] examined potassium auribromide $K[AuBr_4] \cdot 2H_2O$ and found that the ion $AuBr_4^-$ possessed a planar form. The X-ray evidence clearly showed that the water in the auribromide was held as water of crystallisation and that the substance did not contain the 6-covalent complex $[AuBr_4 \cdot 2H_2O]^-$. Recently Burawoy, Gibson, Hampson and Powell [36] examined the dipole moments and crystal structure of some organic derivatives of 4-covalent auric gold. They found that in diethyl-monobrom-gold, which is dimeric, with the constitution



the atoms and groups attached to a 4-covalent gold atom were co-planar with the metal atom. Additional examples, where the configuration of a 4-covalent complex is dependent on principal valency, have been found in the cases of tin and lead. Chemical and physical investigations have clearly shown that the four valencies of stannic tin are tetrahedrally distributed. Pope and Peachey [37] in 1900 prepared an optically active compound of tin and this tetrahedral configuration was also revealed by X-ray methods in stannic iodide [38] and tin tetraphenyl [40]. Until recently no examination had been made of quadricovalent compounds of bivalent tin, but in a preliminary note [39] Cox, Shorter and Wardlaw have now recorded the results of an X-ray analysis of $K_2[SnCl_4] \cdot 2H_2O$. The X-ray measurements show that the tin is 4-covalent and not 6-covalent as the presence of two molecules of water might suggest, and the ion $[Sn^{II}Cl_4]^{2-}$ is planar in contrast with the tetrahedral $[Sn^{IV}I_4]$. Investigations on other stannous compounds support these conclusions. Further, lead, which has a tetrahedral disposition in $Pb(C_6H_5)_4$ [40] and other plumbic compounds, proves to be planar [39] in quadricovalent derivatives such as lead benzoylacetate and $PbCl_4 \cdot 2CS.(NH_3)_2$ where the principal valency of the lead is two. This short summary of some of the results obtained from an examination of 4-covalent complexes of

metals in varying valency states, emphasises the important change in configuration which may accompany a change in principal valency.

The co-ordination compounds of cobalt have always been of great interest but most attention has been directed to those showing cobalt with a covalency of six. In recent years, however, the 4-covalent cobalt complexes have commanded considerable interest for they present a stereochemical problem of a puzzling nature. Two forms of $\text{CoCl}_2 \cdot 2\text{C}_5\text{H}_5\text{N}$ are known, one discovered in 1894 and the other in 1927, and by analogy with the corresponding platinous compounds it has been suggested that they are *cis* and *trans* isomerides of planar structure. Moreover, the tendency to square co-ordination on the part of bivalent cobalt is shown by the close isomorphism of $\text{CoSeO}_4 \cdot 5\text{H}_2\text{O}$ with $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ since, as we have pointed out, the copper atom in the latter substance is surrounded by four water molecules in a plane. In 1935, however, Powell and Wells [41], as a result of an X-ray study of Co_2CoCl_6 , concluded that the ion $[\text{CoCl}_4]^{--}$ was of tetrahedral type. It was obvious from the chemical facts and the X-ray data that the possibility arose that bivalent cobalt might provide a definite example of a metal, in the same valency state, having both planar and tetrahedral quadricovalent derivatives. A chemical and crystallographic investigation of the two forms of $\text{CoCl}_2 \cdot 2py$ and some related compounds was recently undertaken [42] and it was shown that one form of $\text{CoCl}_2 \cdot 2py$ was *trans* planar



No definite conclusion could be drawn regarding the structure of the other form. The demonstration of this planar structure in one form of $\text{CoCl}_2 \cdot 2py$ together with the previously established tetrahedral structure of the $[\text{CoCl}_4]^{--}$ ion appears to constitute the first definite case of a bivalent metal possessing simple unchelated 4-covalent derivatives of more than one configuration. The only other case in which there is evidence for both configurations occurring for an element in one valency state is that of beryllium, the phthalocyanin derivative of which has been shown by Linstead and Robertson [48] to be centro-symmetrical, so that if the beryllium atom has four covalencies they are co-planar. Many quadricovalent derivatives of beryllium have been shown to be tetrahedral, however; these include representatives of all types of complex, e.g. $\text{Na}_2[\text{BeF}_4]$, basic beryllium acetate, $\text{Be}_2\text{O}(\text{CH}_3\text{COO})_4$,

[Be₄H₄O]SO₄, beryllium benzoyl pyruvate, and the mineral hambergite [44] Be₃BO₃(OH), which contains BeO₃(OH) tetrahedra, so that it is perhaps permissible to suggest that in the case of the phthalocyanin derivative the rigid planar character of the organic molecule imposes a configuration which would not be adopted by the beryllium atom in normal circumstances. This appears probable on theoretical grounds since there are no *d* levels in the unexcited beryllium atom. None the less, the result is of great interest as showing the extent to which special conditions may modify configuration.

Finally the case of manganese may be mentioned. As is well known, in its hexa- and heptavalent conditions, *i.e.* in [MnO₄]²⁻ and [MnO₄]⁺, this element has a tetrahedral disposition of valencies. Recently the substance MnCl₂.2py has been shown [42] to be planar, being fully isomorphous with the corresponding cobaltous compound, CoCl₂.2py while the close isomorphism of MnSO₄.5H₂O and CuSO₄.5H₂O has long been recognised. Since also a square configuration occurs in manganite [45] MnO(OH) it appears that manganese is so far unique in exhibiting a planar configuration in two valency states, *viz.* with a principal valency of both 2 and 3.

Our present knowledge of the stereochemistry of quadricovalent metals is summarised in the following table, in which □ represents a planar distribution of bonds and Δ a tetrahedral. The extent of recent advances in this field is well shown by a comparison of this table with a corresponding one given by Sidgwick, *The Covalent Link in Chemistry*, p. 213, published in 1933.

Principal Valency	Ni	Pd	Pt	Cu	Ag	Au	Pb	Sn	Co	Mn †	Be
0	Δ*										
1				Δ	Δ	?					
2	□	□	□	□	□	□	□	□	□ Δ	□ □	Δ □ ?
			Δ				Δ	Δ			

* in Ni(CO)₄.

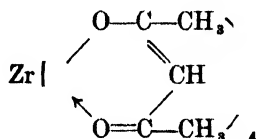
† Δ for principal valency 6 and 7.

If we except the case of beryllium discussed above, it appears that those atoms, whose effective atomic numbers (E.A.N.) in a complex is that of an inert gas, have a tetrahedral configuration; that the converse is not true however is shown by the case of quadri-valent platinum, for which the E.A.N. is 82, four electrons short of the radon configuration. No generalisation appears to be possible

for the planar structures, although the majority of them occur for elements in their bivalent condition. Consideration of the results tabulated above indicates some of the directions in which further progress may be expected. The theoretical work of Pauling from 1931 onwards undoubtedly had a very stimulating effect on experimental work, but on account of the complexity of the problem his results were necessarily only permissive in character, i.e. it was possible to show that the combination of various electron orbitals would result in a definite configuration which could be predicted, but in those cases where from the known electronic configuration of the atom more than one combination of orbitals seems valid, e.g. Mn, then there exists no criterion whereby it is possible to decide which configuration shall actually occur. At the present time experiment has to some extent outstripped theory and it is greatly to be hoped that the application of wave-mechanical methods will, in due course, show why, in certain cases, a change of principal valency results in a change of configuration and why, for example, this is not the case for 6- and 7-valent manganese. A further problem is whether any distinction can be made on theoretical grounds between the covalent and the co-ordinate link; it is significant that those compounds of bivalent cobalt which are planar involve co-ordinate links whereas only covalent bonds occur in the tetrahedral $[\text{CoCl}_4]^-$. In its present state, theory cannot be completely reconciled with experiment in the matter of magnetic properties of co-ordination compounds; this is particularly the case, as Sugden has pointed out, with copper [16] and cobalt [46]. Further work here appears very necessary.

Mention was made in the introduction to this article of a possible co-ordination number of eight. The number of elements which exhibit this covalency is very restricted and the conditions for its realisation are still obscure, in spite of attempts to formulate a satisfactory theory. Most of the elements showing a covalency of eight are heavy elements, although both zirconium and molybdenum with atomic numbers of 40 and 42 respectively are definitely 8-covalent. W. G. Penney and J. S. Anderson [47] have recently discussed co-ordination numbers of eight in a very useful communication, and conclude that eight elements, Zr, Mo, Ru, Ce, Hf, W, As, Th, are known to form co-ordinated complexes with a covalency of eight. In the cases of certain compounds which appear to show this 8-covalency the possibility cannot be overlooked that they may have an alternative constitution. For example, certain salts contain eight molecules of water of crystallisation and these are sometimes represented as being associated with the metal

atom and conferring on it a covalency of eight, *e.g.* $[\text{Be}, 8\text{H}_2\text{O}][\text{PtCl}_4]$. It seems not unlikely, however, that the water molecules exist as double water molecules as suggested by Werner and that actually the covalency of beryllium is the normal one of four. Again, complex fluorides are known of the type K_2HMF , where M is Ta, Sn or Pt. These may actually be crystalline aggregates of two or more molecules as in the well-known case of $(\text{NH}_4)_2\text{HfF}_6$, which has been shown by X-rays to be made up of units of $(\text{NH}_4)_2\text{HfF}_6$ and NH_4F so that here the hafnium has not a covalency of seven but six. It is generally presumed that the distribution of the valencies of an 8-covalent atom is cubic, but it is very remarkable that in the cases of the tetra-acetylacetonates of metals such as zirconium, no isomers have been detected.



It will be apparent that investigations on the lines indicated in this article are capable of wide extension to elements of other covalencies such as odd covalencies of three, five or seven. The results already recorded are of fundamental importance to modern stereochemistry, both in themselves and as a stimulus to advances from other directions, *e.g.* in the application of quantum mechanical considerations to valency problems. The attention of those who wish to learn more of other aspects of co-ordination compounds is directed to the account [48] of a symposium on complex compounds held by the American Chemical Society in 1936, when L. F. Audrieth [48] emphasised that from a purely practical point of view there is also every reason for a more detailed study of complex inorganic compounds. Sir Gilbert Morgan [49], too, has stressed that at least one important metallurgical industry—the production of pure nickel—may be regarded as being dependent on the singular properties of a co-ordination complex, nickel carbonyl.

REFERENCES

1. WERNER, *Ber.*, 1911, **44**, 3132.
2. — *ibid.*, 1912, **45**, 433 (Fe'').
THOMAS, *J.C.S.*, 1921, **119**, 1140 (Fe''').
3. WERNER, *Ber.*, 1911, **44**, 1887; JÄGER and THOMAS, *Proc. Akad. Amst.*, 1919, **21**, 693.
4. MORGAN and BURSTALL, *J.C.S.*, 1931, 2213.
5. CHARONNET, *Compt. rend.*, 1924, **178**, 1423; *Ann. Chim.*, 1931, **16**, 126.
BURSTALL, *J.C.S.*, 1936, 173.

6. WERNER, *Ber.*, 1914, **47**, 1954.
7. DELEPINE, *Compt. rend.*, 1914, **159**, 239.
8. WERNER, *Vierteljahrschrift Nat. Ges. Zurich*, 1917, **62**, 553.
9. See *Electronic Theory of Valency* (Oxford, 1927).
10. *J.C.S.*, 1920, **117**, 86, 889; *ibid.*, 1921, **119**, 105, 687.
11. *Ibid.*, 1929, 560.
12. *J. Amer. Chem. Soc.*, 1922, **44**, 2404.
13. *Ibid.*, 1931, **53**, 1367.
14. *J.C.S.*, 1932, 246.
15. *Ibid.*, 1935, 459.
16. *Nature*, 1936, **137**, 543.
17. PINKARD, SHARRATT, WARDLAW and COX, *J.C.S.*, 1934, 1012.
18. GRÜNBERG and PTIZYN, *J. pr. Chem.*, 1933, (ii), **136**, 143.
19. *J.C.S.*, 1935, 839.
20. See COX, PINKARD, WARDLAW and WEBSTER, *ibid.*, 1935, 459.
21. COX, WARDLAW and WEBSTER, *ibid.*, 1935, 1475.
22. *Ibid.*, 1926, 3121.
23. BEEVERS and LIPSON, *Proc. Roy. Soc., A*, 1934, **146**, 570.
24. *J.C.S.*, 1935, 731.
25. *Ibid.*, 1935, 615.
26. *Z. Krist.*, 1936, **93**, 136.
27. *J.C.S.*, 1936, 129.
28. COX and WEBSTER, *Z. Krist.*, 1935, A, **90**, 561.
29. BROCKWAY and CROSS, *J. Chem. Physics*, 1935, **3**, 828.
30. *Naturwiss.*, 1935, **23**, 320.
31. *Ber.*, 1936, **69**, 1692.
32. *J.C.S.*, 1936, 775.
33. *Ibid.*, p. 1503.
34. COX, WARDLAW and WEBSTER, *J.C.S.*, 1936, 775.
35. *Ibid.*, 1936, 1635.
36. *J.C.S.*, 1937, 1690.
37. *Proc. Chem. Soc.*, 1900, **16**, 42, 116.
38. R. G. DICKINSON, *J. Amer. Chem. Soc.*, 1923, **45**, 958.
39. *Nature*, 1937, **139**, 72.
40. W. H. GEORGE, *Proc. Roy. Soc., A*, 1927, **113**, 585.
41. *J.C.S.*, 1935, 359.
42. *Ibid.*, 1937, 1556.
43. *Ibid.*, 1936, 1736.
44. W. H. ZACHARIASEN, *Z. Krist.*, 1931, **76**, 289.
45. M. J. BUEGER, *Z. Krist.*, 1936, **95**, 163.
46. BARKWORTH and SUGDEN, *Nature*, 1937, **139**, 374.
47. *Trans. Faraday Soc.*, 1937, **33**, 1363.
48. *Chem. Reviews*, 1936, **19**, 55.
49. Obituary notice of Alfred Werner by G. T. MORGAN, *J.C.S.*, 1920, **117**, 1639.

GEOLOGY IN THE U.S.S.R.

By G. W. TYRRELL, A.R.C.Sc., D.Sc., F.G.S., F.R.S.E.

The University of Glasgow

THE meeting of the 17th International Geological Congress in Moscow in July 1937, and the numerous excursions held both before and after the Congress, afforded a good opportunity of assessing the present state of geological science in that vast region, covering one-sixth of the land surface of the globe, which is comprised in the Union of Socialist Soviet Republics.

The 16th Congress held at Washington in 1933 attracted 1182 applicants of whom 836 were Americans and 346 foreigners. Of this number 665 delegates actually attended. The corresponding figures for the 17th Congress are not yet known, but are tentatively given as follows. Over 2000 applications for membership were made of which about 400 were from foreigners, and about 1000 delegates attended the Congress meetings. It may be of interest to give a general account of the activities of the Congress held, as it was, in the exotic environment of Soviet Russia.

The general assemblies of the Congress were held in the auditorium of the Moscow Conservatory, the hall in which the major musical events of Moscow take place. During the evening of July 20, the day prior to the opening of the Congress, an excellent exhibit of the mineral resources of the U.S.S.R., displayed in the foyer and galleries of the Conservatory, was opened for public inspection. A large new geological map of the U.S.S.R., liberally covered with tablets indicating the loci of the economic minerals and rocks, was the object of much attention.

The Congress was opened on the morning of July 21 by Dr. Philip S. Smith, leader of the American delegation, who officiated as retiring President in the place of Professor W. Lindgren who was unfortunately absent owing to illness. After his opening speech Dr. Smith gave the floor to V. I. Mezhlauk, Peoples Commissar of Heavy Industry, who delivered a speech of welcome to the Congress in the name of the Soviet Government. Mezhlauk was followed by I. M. Goubkin, Vice-President of the Academy of

Sciences, who had been elected President of the Congress and had taken the chair, and by V. I. Komarov, President of the U.S.S.R. Academy of Sciences, who gave an address of welcome in the name of the Academy.

The perhaps not unjustified nor unnatural political references made by the Russian speakers, intent on advertising the achievements of a Socialist society, sounded oddly, however, in a scientific congress. Vehement and prolonged applause, for example, during which the whole audience rose to its feet, greeted Mezhlauk's reference to the "leadership of the Communist Party and comrade Stalin," under which the recent tremendous advances in Soviet geology had become possible; and equal applause was accorded to Goubkin's phrase: "All these successes we owe to our great Communist Party and the Soviet Government, which have created for our scientific work such conditions for which we pride ourselves before the whole world." It is but fair to say, however, that after the political ebullience of the first plenary meeting, when the Congress had settled down to its real scientific work, political allusions became extremely rare.

During the afternoon Goubkin read a paper on "The Estimation of the World's Oil Reserves," in which a somewhat optimistic method of estimation was outlined which credits the U.S.S.R. with "proved" reserves of 3877.2 million tons, with a "possible" further reserve of 2500 million tons.

The language difficulty was most efficiently overcome by the adoption of the League of Nations system of translation, for the first time, I believe, in a scientific congress. Below the speaker's rostrum stood a row of cubicles in which translators spoke into microphones, the languages used being Russian, English, French, German, Italian and Spanish. Their voices were transmitted to headphones attached to every chair in the auditorium, and listeners had only to plug in to the appropriate pair of terminals on their chairs to hear the speeches in their own language or in the language they best understood. For a purely scientific paper written translations were made beforehand and read simultaneously with its delivery, but the ordinary business of the Congress was translated extemporaneously by an extremely efficient corps of translators.

The morning of July 22 was devoted to sight-seeing, visits to museums and other cultural and educational institutions in Moscow. During the afternoon the second plenary meeting of the Congress was held in the Conservatory. The first item was a paper by M. M. Prigorovsky on "The Coal Provinces and Basins

of the U.S.S.R.”; the second was the entry of about 30 Young Pioneers of both sexes, who filed on to the platform in their picturesque black and white uniforms with red neckties. These were introduced as young naturalists and geologists in training to take their places in the investigation of Soviet natural resources. Their leader stood forward and delivered a short address of welcome to the Congress, which received great applause. Then came my turn, for I had learned only the day before that I was expected to give my paper on “Igneous Activity in Relation to Tectonics” to the general assembly, although I had prepared it only for a sectional and not a full-dress occasion. I found my speech somewhat of an ordeal under the prevailing conditions. Not only was there the confused murmur of the translators below me, but a movie camera with its attendant pair of arc-lights was perambulating the area, with the lights intermittently focussed on me as well as spot-lights from the gallery, while press photographers thrust their cameras almost under my nose. The fourth and concluding item was a paper by Professor A. D. Archangelsky on “Geological Results of General Magnetometrical and Gravity Work in the U.S.S.R.”

In the evening many members of Congress attended by invitation a fine open-air theatre performance in the Central Park of Rest and Culture. A meeting of the general assembly at this centre before the performance, at which Professor O. J. Schmidt, the chief of the Soviet Arctic Scientific Service, was to speak on “Investigation of the Arctic Regions,” had to be cancelled to the general regret, owing to the unfortunate death of Madame Schmidt.

Sectional meetings had begun on the afternoon of Wednesday, the 21st of July, and were continued on Friday the 23rd, and on Monday, Wednesday and Thursday of the following week. An account of the work of the sections follows later.

During the week-end 300 members of Congress made a trip to Leningrad, where visits were paid to art galleries and museums, and to the former palace of the Czars at Peterhof on the southern shore of the Gulf of Finland, where the party was entertained to a banquet by the Leningrad Soviet. The high lights of the Leningrad excursion were the visits to the Museum of the Central Geological and Prospecting Institute, the Mining Museum where a wonderful mineral collection was exhibited, and the Zoological Museum in which we saw the famous fossil carcass of the woolly mammoth, which was extracted almost whole, with flesh and entrails preserved, from a frozen Siberian swamp.

On Tuesday, July 27, the entire Congress was taken for a day's trip on the new Moscow-Volga Canal which had been opened by

Stalin only a fortnight previously. The Canal is an impressive piece of work, and forms the final link in a chain of interior waterways which now unites the White Sea, the Baltic, the Black Sea, the Sea of Azov, and the Caspian. In the evening we returned to a banquet and entertainment given by the Moscow Soviet in the Khimki terminal canal station.

Next evening the Congress attended a Government reception in the Kremlin which was held in the great white marble hall of St. George. Molotov, Commissar for Home Affairs, was in the chair. Molotov and Mezhlauk extended welcomes on behalf of the Soviet Government, and Dr. Philip S. Smith (U.S.A.), Dr. E. B. Bailey (U.K.), and Professor Jacob (France) replied on behalf of foreign members of Congress. At intervals during the banquet the visitors were given a magnificent entertainment by the great Moscow Orchestra of 120 performers, and by a long succession of stars from the Moscow opera, ballet, theatre and music hall.

The third and final plenary meeting of Congress was held on Thursday, July 29, at which it was decided to hold the next International Geological Congress at London in 1940.

The sectional work of the Congress was voluminous and invigorating. Even a superficial perusal of the published volume of *Abstracts of Papers* (English-French edition, 240 pp.) shows that Soviet geology is vigorous and flourishing. The Organisation Committee of the Congress had suggested nine main subjects for discussion. These were :

1. The Petroleum Problem and the Petroleum Resources of the World.
2. Geology of Coal Fields.
3. The Pre-Cambrian and the Mineral Deposits in the Regions of its Development.
4. The Permian System and its Stratigraphic Position.
5. Correlation of Tectonic Processes, Magmatic Formations and Ore Deposits.
6. Tectonics of Asia.
7. Problems of Geochemistry.
8. Geophysical Methods in Geology.
9. Geology of the Arctic Regions.

From the volume *Abstracts of Papers* which was published in a Russian as well as in an English-French edition, we find that "The Petroleum Problem and the Petroleum Resources of the World" attracted 48 papers, of which no less than 43 were by Russian authors, who gave collectively a very complete conspectus of the oilfields, old and new, of the U.S.S.R., and of new methods

of prospecting and of estimating oil reserves. The discussion on the "Geology of Coal Fields" produced 42 papers, of which all but six were by Russian authors, and dealt with the geology, tectonics, palæontology, petrology and resources of the vast Soviet coal regions. Thirty-three papers were contributed to the section on "The Pre-Cambrian," of which 25 were by Russian authors, and 24 dealt with the stratigraphy, tectonics, petrology and ore-deposits of the Pre-Cambrian of the U.S.S.R., the remaining paper dealing with a nomenclatorial question. The "Permian System and its Stratigraphic Position" was dealt with in 50 papers, of which 41 were by Russian investigators, giving a complete summary of the Permian system throughout the U.S.S.R., with notes on palæontology, conditions of sedimentation and economic materials. A valuable series of 55 papers on the "Correlation of Tectonic Processes, Magmatic Formations and Ore Deposits" was given, of which 33 were by Russian authors. This subject, with its wide general appeal, naturally attracted a large proportion of foreign authors. Not the least valuable feature of this series was a number of papers on the distributional relations of igneous rocks and ore deposits in various parts of the U.S.S.R. Of the 49 papers presented to the section on "Tectonics of Asia," only 29 were Russian, and some of these dealt with European Russia. Several of the remainder treated general tectonic problems; others described the tectonics of China, Japan, Java, the Himalayas, Iran, Arabia, Anatolia, N.W. Africa, and the West Indies. Twenty papers were given in the section on "Problems of Geochemistry," 16 of which dealt with Russian ore deposits and petrographical fields. Some of these papers could have been placed with equal propriety in the section on Tectonic Processes, Magmatic Formations and Ore Deposits. To the section on "Geophysical Methods in Geology" 26 papers were presented, of which 21 were by Russian authors, but only eight dealing with specifically Russian topics. Papers on radioactivity and geology, and on the determination by radioactivity methods of the ages of minerals and of the earth, were included in this section. The "Geology of Arctic Regions" produced 17 papers, of which all but one were by Russian authors and dealt with the Arctic regions of the U.S.S.R.

In addition to the above a symposium on "Palæozoic and Pre-Cambrian Climates" was held, to which 25 papers were contributed. This produced, among others, a most interesting series of papers on Palæozoic and Pre-Cambrian glacial deposits of world-wide distribution, but only three papers were specifically Russian. There were also 30 papers in a concluding section headed "Miscellaneous,"

some of which might have found places in preceding sections. Probably these papers arrived too late for classification, as certainly did a series of 22 papers published in an "Additional Abstracts of Papers" of 16 pages. Thus, in all, 422 papers were presented to the Congress, of which 304, or 72 per cent., were by Russian authors. These dealt chiefly with Russian geological subjects, the remainder being on more general topics.

From a perusal of *Abstracts of Papers* it seems clear that, while some of the new Russian material is of purely local interest, much of it is of more than local importance, and is worthy of incorporation in the general body of geological science. It is to be hoped, therefore, that when the papers come to be published in full in the Proceedings of the Congress, they will be written in English, French or German; or if, as will no doubt be necessary, there is a Russian edition for internal consumption, there should also be a non-Russian edition for the benefit of those foreign members—the great majority—to whom Russian is a sealed book.

The Congress excursions had been in preparation for two years and were, from all reports, and from my own experiences, very efficiently conducted. They varied in length from 19 to 35 days; the shorter came mainly before, the longer after the Congress at Moscow. The excursions were as follows:

Before the Congress:

- A 1. The Northern Excursion to Russian Karelia and the Kola Peninsula. 19 days.
- A 2. The Southern Excursion, visiting the Kursk Magnetic Anomaly District, the Donetz Coal Basin, the Crimea and the Ukraine. 19 days.
- A 3. The Volga Excursion (cancelled).
- A 4. The Caucasus Excursion. 19 days.
- A 5. The Permian Excursion, visiting the Volga Region in the neighbourhood of the Samara bend, the southern Urals, and the classic Perm Region. 19 days.

After the Congress:

- C 1. The Petroleum Excursion, visiting the new Volga and western Ural oil-fields, Azerbaijan, Daghestan, North Caucasus, Maikop, Baku and the Taman Peninsula. 35 days.
- C 2. The Siberian Excursion, visiting the Urals in the triangular area between Sverdlovsk, Cheliabinsk and Ufa, the Novosibirsk region and the Kuznetsk Coal Basin in West Siberia, the gorge of the Yenesei between Krasnoyarsk and Minussinsk, and the Mongolian autonomous district

of Khakassk in south central Siberia. 35 days. (This excursion was originally planned for 50 days, and was intended to visit Lake Baikal and Vladivostok, but the latter part was cancelled owing to the political troubles in the Far East.)

C 3. Excursion to Novaya Zemlya in the Arctic Ocean. 23 days.

C 4. The Urals Excursion, visiting the metalliferous belts of the central and southern Urals. 22 days.

C 5. Short excursion to localities near Moscow. 3 days.

The enormous distances of the U.S.S.R. made necessary the employment of special trains on which the excursionists lived and slept. Foot, riding, motor and steamer excursions were made at selected points from the train. Henceforward I am writing of my own experiences. Wherever possible the train was halted for the night on sidings, and at every such halt two armed policemen unobtrusively patrolled the train, probably to protect us from unauthorised intrusion. At every important town there was a municipal reception, and at provincial capitals we were usually entertained to a banquet by the local authorities. At Krasnoyarsk in Siberia a new siding adjacent to the building in which the reception was held had been built for the Congress train, and the whole enclosed by a high wooden paling. The purely geological outings were interspersed with visits to museums, state and collective farms, and various social institutions. At every main halt on the railway, and over the entrances to mines, quarries, industrial plants, collective farms, or institutions that we visited, was a strip of red bunting with the inscription: "Welcome to the 17th International Geological Congress" in English, French and Russian. This was sometimes supplemented by a quotation from a speech by Stalin: "Science is called science just because it recognises no fetishes, and does not fear to raise its hand against everything that is obsolete and antiquated, and listens attentively to the voices of experience and practice," also in the above three languages.

Everywhere the most elaborate preparations had been made for our comfort, and for easy and rapid inspection of outcrops, quarries, railway cuttings and mines. New plankways made the rough places smooth; new wooden stairways and bridges facilitated the ascent and descent of railway embankments and quarry faces; sections were newly cut in mines or cleaned of accumulated mine dust and mud, and powerful arc lamps were installed at critical points. At Stalinsk thousands of tons of rock had been excavated from the side of a hill to expose a clear section of the coal measures of the Kuznetzk Basin. At most points of geological interest boards had

been erected on which were displayed plans, sections and maps, and an abundant supply of museum specimens of minerals and rocks had been already prepared for our acceptance. Twenty-four well-printed and well-illustrated guide books in a Russian, and in a French and English edition, were provided to elucidate the geology of the regions visited. A manager, courier, and a number of interpreters accompanied each excursion. While the quality of the leadership naturally varied, it was, on the whole, excellent.

The organisation that sustains and directs the greater part of the vast and varied geological activity in the U.S.S.R. is the Central Institute of Geology and Prospecting which has its headquarters in Moscow, and is included under the Peoples' Commissariat of Heavy Industries. It is said that no less than 6000 geologists (one account said 12,000) were in the field during 1937. The Central Geological Research Museum (the Tchernychev Museum) at Lenin-grad is perhaps the most important institution under the ægis of the Central Institute; but there is a large number of provincial museums and provincial "Geological and Prospecting Trusts" which are quasi-independent, and whose relations to the Central Institute are hard to define or, at any rate, difficult to make out. Guide books describing the functions and work up to date of both the Central Institute and the Tchernychev Museum were issued to members of Congress.

The old Geological Committee, founded in 1882, was entrusted with the task of preparing the geological map of European Russia, but the money and personnel allotted to it were totally insufficient to achieve this aim. Nevertheless it served the purpose of bringing into European prominence a galaxy of brilliant Russian geologists of whom A. Karpinsky, Th. Tchernychev, F. Loewinson-Lessing and V. Obruchev achieved world-wide fame. In 1918 only 10.25 per cent. of the country was geologically known; only 0.25 per cent. was covered by geological maps on the scale of 1 : 200,000 and only 0.45 per cent. on the scale of 1 : 10,000. After the Revolution the Geological Committee took on a new lease of life and played a great part in the economic reconstruction of the country. In 1929 the Geological Committee was completely reorganised into a series of institutes that dealt respectively with geological surveys, metallic ores, coal, non-metalliferous deposits, hydrogeology, geophysics and borings. Two years later the Central Institute of Geology and Prospecting was organised and took over the whole of this work. Enormous sums of money have been allocated to geological work by the Soviet Government. It is stated that in 1936 alone more than one milliard of roubles was allotted in the

U.S.S.R. for geological and prospecting work.¹ The budget of the Central Institute has increased from 2,886,000 roubles in 1931 to more than 12,000,000 roubles in 1936. The scientific personnel of the Institute numbers 500.

The organisation of the Institute is based on the principle of division into regional and specialised groups which, between them, undertake geological work of all kinds over the whole territory of the U.S.S.R. There are 20 of these groups distributed as follows :

Regional groups : European Russia ; Crimea and Caucasias ; Urals and Bashkiria ; Siberia ; Kazakstan ; Central Asia ; the Soviet Far East ; and Yakutia.

Specialised groups : Geology and tectonics ; petrology and mineralogy ; palaeontology and stratigraphy ; ores of tin and the rare metals ; non-metalliferous deposits ; fuels (with section on the petrography of coal) ; metallic ores (with a minerographical laboratory) ; lithology (? building stones and road metals) ; geochemistry ; hydrogeology ; geophysical methods of prospecting ; boring and mining ; statistics of mineral resources and maps.

The above-mentioned pamphlet goes on to describe in some detail the enormous amount of geological work that has been accomplished in each of these branches. It is impossible to give details here, and it may be sufficient to say that a new general colour-printed geological map of the U.S.S.R. in eight sheets on the scale of 1 : 5,000,000, based on the recent work of the Institute, was presented to every member of the Congress. It is beautifully executed and excited general admiration.

The work of the Central Geological and Prospecting Scientific Research Museum (Tchernychev Museum), to give it its full title, at Leningrad, is described in a *General Guide to the Museum* (English edition, 77 pp.), which was issued to members of Congress. The inception of this museum dates from the formation of the old Geological Committee, but the fine building in which the collections are now housed was only completed in 1914. Its staff now numbers 62, and its budget for the years 1931-36 amounted to between 300,000 and 400,000 roubles per annum. The general aim of the museum is to illustrate the geological structure of the U.S.S.R. and its mineral resources. In more detail it is intended (1) to acquaint the trained geologist and prospector with what has already been done in regard to the geology and mineral resources of the

¹ This is hard to credit, and there is probably some mistake. A milliard (1,000,000,000) of roubles is £40,000,000 at the tourist rate of exchange, and over £10,000,000 at the real rate. The statement appears in the pamphlet *L'Institut de Géologie et de Prospection* (1937, p. 2), issued to the Congress.

U.S.S.R. ; (2) to assist in the training of new cadres of geologists and prospectors ; and (3) to promote wide popularisation of geological knowledge among the Soviet workers, and help them to understand the basic importance of the science in the fulfilment of the successive Five-Year Plans. The last-mentioned aim is regarded as one of the most important functions of the museum, and is carried out by means of numerous simplified headings, legends, labels and explanatory notes on the exhibits, the organisation of popular exhibitions in the museum and of circulating exhibitions, ordinary lectures and cinema lectures, and of geological excursions for the general public in the environs of Leningrad. Furthermore, the museum sends out special parties and larger expeditions with the objects of securing new collections, as well as completing and duplicating existing collections.

The great Museum of Mines at Leningrad was also the subject of a special guide-book (in French) which was issued to the Congress. This museum was initiated soon after the establishment of the St. Petersburg Institute of Mines in 1773. It was visited by the Congress and its magnificent exhibits were greatly admired. The exhibits are grouped in four main sections : mineralogy ; mining technique ; geology ; and petrography. The mineralogical section comprises the sub-sections of geochemistry, crystal structure and chemistry, systematic mineralogy, genetic mineralogy, and artificial minerals (slags, cements, etc.) ; the geological section is divided into sub-sections dealing with the Quaternary, Tertiary to Pre-Cambrian, vertebrate palaeontology, invertebrate palaeontology with palaeobotany, and physical geology ; the petrographical section has two sub-sections on ore deposits in general, and the mineral deposits of the Leningrad Province (which includes the Kola Peninsula) and Karelia.

Many excellent provincial museums were visited during the Congress excursions, but there is only space enough to mention two of these which were seen by the author, namely, the local museum of Kirovsk, the new phosphate town in the Kola Peninsula, which contains one of the finest collections of rare minerals and rare-earth minerals in the world ; and the brand-new Urals Geological Museum at Sverdlovsk which was completed just in time for the visits of the Uralian and Siberian excursions. The exhibits in this great museum completely cover the geology, tectonics, petrology, mineralogy and ore deposits of the whole vast length of the Urals from the Arctic to the Caspian.

The U.S.S.R. Academy of Sciences carries on a very considerable amount of geological research, but the relations of its geological

sections with the Central Institute of Geology and Prospecting are obscure, and it was gathered that there was a certain amount of rivalry between the two institutions. From an article in *Nature* (Jan. 16, 1937) on "The U.S.S.R. Academy of Sciences and the Third Five-Year Plan" we learn that one function of the Academy is to study the natural resources and productive forces of the country, and to promote their rational utilisation. Geology and ore deposits would naturally come within this field of activity. Expeditions are sent out and branches of the Academy have been established in various regions to direct the work of prospecting and surveying. The first preliminary general survey of the geological, chemical and economic resources of the country has already been completed. With regard to the Third Five-Year Plan, the activities of the Academy are to be directed to ten main problems, of which the first is to develop geological, geochemical and geophysical methods of prospecting for useful minerals, particularly tin, rare metals and oil. The Academy sustains a number of great museums and research institutions, such as the Lomonossov Institute, the Petrographical Institute directed by Loewinson-Lessing, the famous doyen of Russian petrology, the Soil Institute, and the Geological Institute with its museums, the Karpinsky Museum and the Palæontological Museum.

The great monograph on the *Minerals of the Khibina and Lovozero Tundras* (Russian), published by the Lomonossov Institute of the Academy of Sciences, illustrates extremely well the degree of co-operation that obtains between various Soviet research institutions in attacking a specific problem. This work has also been published in an abridged English edition (1937, 152 pp.), which gives a brief account of the petrography of this wonderful region of alkaline igneous rocks, and a detailed account of the crystallography and optical properties of its numerous rare minerals.

The preface to the English edition recounts the history of research in this region, and from it we gather that in 1920 the U.S.S.R. Academy of Sciences, in collaboration with the Institute for Northern Exploration (? the Arctic Institute), began a systematic study of the petrology and mineralogy of the great ring-shaped massifs of Khibina and Lovozero under the general direction of A. E. Fersmann. The abundance of apatite-rich rocks in the Khibina mass was established in 1925, and their first sampling on a commercial scale took place in 1928. In 1929 a comprehensive economic development of the Khibina region was inaugurated. The Scientific Institute of Fertilisers began commercial prospecting for apatite and nepheline rocks, and the Apatite Trust began the

technical and industrial development. They built new villages and the new town of Kirovsk, now approaching a population of 40,000. Hundreds of miles of electric railways were constructed, linking Kandalaksha at the head of the White Sea with Murmansk and Kirovsk. Three other organisations, the Central Geological and Prospecting Institute, the Rare Metals Trust, and the Leningrad Geological Trust, have joined in the work.

Thus, at the present time, owing to the close collaboration of the seven above-mentioned scientific, industrial and technical organisations, apatite (phosphate ore) is being mined at the rate of 2,000,000 tons per annum, and a reserve of 2,000,000,000 tons has been established. I regard the Kukisvumchorr Apatite Mine, developed in eight years, as one of the industrial wonders of the world. There are over 20 miles of underground galleries seven feet in height, electrically lit, and with electric haulage. A tunnel which admits the ordinary freight train has been excavated to the heart of the ore mountain to facilitate loading. The mineral nepheline is also mined for use in the ceramic industry, and for its content of potash as fertiliser. The new mineral *lovchorrite*, a massive form of rincolite, chemically a fluorine-bearing titanosilicate of calcium, strontium and sodium, with up to 20 per cent. of rare earths, is mined from pegmatites at the rate of several hundred tons per annum. The new mineral *loparite* (titanoniobate of cerium, calcium and sodium) also occurs in deposits of economic importance. Sphene is mined at the new Yukspor mine, but for what reason is unknown. The social and industrial development of the region which, nine years ago, was a desolate Arctic waste peopled by a few Lapp families, has kept pace with its technical and scientific development.

In conclusion, we may remark on the means of publication, old and new, whereby the enormous volume of new Soviet geological work is transmitted to the general and scientific public. All Soviet newspapers and magazines publish popular accounts of new scientific developments, and geological articles are very frequently encountered in the popular press. As regards scientific publication the Central Institute has its own *Transactions of the United Geological and Prospecting Service of the U.S.S.R.* published in fascicules. Provincial geological trusts have their own publications, such as the *Bulletin of the Geological and Prospecting Trust of West Siberia*, published in Tomsk. *Problems of Soviet Geology* is a publication of short general and special articles which has appeared in annual volumes consisting of several parts since 1931, under the auspices of the Central Institute of Geology and Prospecting. It resembles the supplementary volumes of the *Summary of Progress* published

by the Geological Survey of Great Britain. The U.S.S.R. Academy of Sciences publishes many geological papers in its *Bulletin* and *Comptes Rendus*, and its various institutes publish memoirs such as that above-mentioned on the "Minerals of the Khibina and Lovozero Tundras" which appeared under the auspices of the Lomonossov Institute. A *Bulletin of the Kamchatka Volcanological Station* has recently been started under the auspices of the Loewinson-Lessing Petrographical Institute, the first number of which has been published in an English translation. The Institute of Geology of the Academy of Sciences of the Ukrainian S.S.R. publishes a *Journal of Geology* on the same lines as *Problems of Soviet Geology*, which has reached its third annual volume.

A number of publications appear to be independent of the two main organisations of geological research, but they may be subject to supervision by them, and are almost certainly subsidised by the State. Among these are the *Memoirs of the Russian Mineralogical Society*, of which a special volume was published for the 17th International Geological Congress, containing a number of reviews of progress in various branches of mineralogy and crystallography in the U.S.S.R. during recent years. V. Sobolev's paper "Progress of Petrography in the U.S.S.R. for the last 20 Years (1917-37)" is translated *in extenso* into English; and D. S. Korjinsky's important paper on "Dependence of Mineral Stability on Depth" is similarly treated. A series of *Transactions of the All-Union Scientific Research Institute of Economic Mineralogy* (octavo) is published; and I find among the literature acquired during the Congress a paper in small quarto size by N. Fedorovsky on "Progrès des Instituts scientifiques de l'U.R.S.S. dans le domaine de la minéralogie appliquée" (pp. 983-1002), which has obviously come from a large volume, but there is no indication of the publication in which it appears. Geological papers are published in the *Bulletin of the Society of Naturalists of Moscow, Geological Section*; and many of the *Transactions of the Arctic Institute* are devoted to geology. This survey of Russian geological literature and publications is necessarily incomplete, for numerous technical and industrial organisations also publish geological work. The great majority of the papers are published with short summaries in English, French or German.

RECENT ADVANCES IN SCIENCE

MATHEMATICS. By J. H. C. WHITEHEAD, M.A., Balliol College, Oxford.

THE THEORY OF GROUPS: 1.—Groups first came to be recognised as such in the form of transformation groups. A set of $(1 - 1)$ transformations of some set of objects into itself is called a group if

1. *The resultant of any two transformations in the set also belongs to the set.*
2. *The inverse of each transformation in the set also belongs to the set.*

For example, taking the objects which are transformed, to be integers, the set of transformations given by $n \rightarrow f_a(n) = n + a$, where a is any integer, constitute a group. For, denoting this transformation by T_a , the resultant $T_b T_a$, of T_a followed by T_b , is T_{a+b} , and T_a^{-1} , the inverse of T_a , is T_{-a} . Examples of sets of transformations which are not groups are the set of all transformations T_a , where $a \geq 0$, and of all transformations T_{2r+1} , where r is any integer, positive or negative. In the first case the first, but not the second, condition is satisfied and in the second case the second condition, but not the first.

Groups played an important part throughout the last century in many branches of mathematics. In geometry they were used by Klein as the basis of his famous answer to the question, "What is Geometry?" For Klein a space was a set of objects, called points, in which there is a definite transformation group. The geometry of such a space is the study of properties which are invariant under the transformations of the group. In other words, if a "figure" is taken to mean a set of points in the space, two figures F and F' , are described as "equal," or "equivalent," if there is a transformation of the group under which F corresponds to F' . Thus the conditions for a group give us the conditions which are familiar in Euclidean geometry,

1. If $F = F'$ and $F' = F''$, then $F = F''$.
2. If $F = F'$ then $F' = F$.

It follows that figures fall into mutually exclusive classes, two

figures belonging to the same class if, and only if, they are equivalent, and an invariant of the group is some property that is shared by all the figures in any one of these classes. For example, the property of being a right-angled triangle is invariant under the Euclidean group in the plane, consisting of transformations of the form

$$\begin{aligned}x' &= x \cos \theta - y \sin \theta + a \\y' &= x \sin \theta + y \cos \theta + b.\end{aligned}$$

Projective geometry is the study of properties which are unaltered by the group of projective transformations, and inversion geometry, and other standard types of geometry (hyperbolic, elliptic, etc.), may be similarly defined.

Groups also figured largely in the theory of functions, the theory of algebraic equations, the theory of differential equations and in various branches of physics. For example, the characteristic property of elliptic functions is double periodicity, meaning that $f(z') = f(z)$ if $z = x + iy$ corresponds to $z' = x' + iy'$ in some transformation of the group

$$x' = x + m\alpha, \quad y' = y + n\beta,$$

where m and n are integers and α and β are the periods. From this point of view elliptic functions appear as a special case of automorphic functions, which are invariant, in the sense just described, under the transformations of some discrete group.

In the theory of algebraic equations the group of permutations of the roots is important. Thus a symmetric function of the roots is one which is invariant under the transformations of this group. The Lie theory of continuous groups was largely developed for its application to partial differential equations and differential invariants. In physics the electro-magnetic theory of light, and later special relativity, is based on the theory of invariants under the Lorentz group. Also any kind of symmetry (*e.g.* in the theory of crystal structure or, more recently, where spherical symmetry is required in cosmology) is a form of invariance under the transformations of some group.

Thus transformation groups played a leading part in the developments of the last century. Early in this century it was realised that groups could be studied "abstractly" or, better perhaps, "intrinsically," as a set of objects which combine according to a certain "abstract" law of multiplication. Nowadays a group is usually defined as a set of one or more objects, called the elements of the group, which satisfy the following conditions:

1. With any ordered pair a and b , is associated a third, which is denoted by ab (in general $ab \neq ba$).
2. The associative law holds. That is to say

$$a(bc) = (ab)c.$$

3. There is at least one element, e , called a (left) unit element, such that

$$ea = a$$

where a is any element in the group, e being independent of a .

4. To each element a , and any (left) unit element e , corresponds at least one element a^{-1} , called a (left) inverse element of a , such that

$$a^{-1}a = e.$$

From induction on n and the second condition it follows that the product $a_1 \dots a_n$, of any ordered set of n elements is uniquely defined as

$$\begin{aligned} a_1 \dots a_n &= (a_1 \dots a_{n-1})a_n \\ &= (a_1 \dots a_i)(a_{i+1} \dots a_n) \end{aligned}$$

for any value of i ($i = 1, \dots, n-1$).

Replacing a by a^{-1} , any left inverse element corresponding to a and e , and writing $a^{-1}a$ for e in 3, we have

$$a^{-1}aa^{-1} = a^{-1}.$$

Multiplying on the left by an element a^* , which is a left inverse corresponding to a^{-1} and e , we have

$$eaa^{-1} = e.$$

Since $e(aa^{-1}) = aa^{-1}$, it follows that

$$aa^{-1} = e.$$

That is to say, a is a left inverse of a^{-1} and a^{-1} is also a "right" inverse of a . From this it follows that

$$ae = a(a^{-1}a) = (aa^{-1})a = ea = a.$$

Therefore any left unit element is also a "right" unit element.

From these results it follows that any equation of the form

$$ax = b,$$

where a and b are given and x is an unknown element in the group, has at least one solution, namely $a^{-1}b$. For

$$\begin{aligned} a(a^{-1}b) &= (aa^{-1})b \\ &= eb \\ &= b. \end{aligned}$$

Similarly, using the fact that any left-unit element is also a right-unit element, we have

$$\begin{aligned}(ba^{-1})a &= b(a^{-1}a) \\ &= be \\ &= b.\end{aligned}$$

Therefore the equation

$$xa = b$$

is satisfied by ba^{-1} . Moreover, these solutions are unique. For if $ax = ax'$ we have

$$\begin{aligned}x &= ex = (a^{-1}a)x = a^{-1}(ax) = a^{-1}(ax') \\ &= (a^{-1}a)x' = ex' = x' .\end{aligned}$$

Similarly if $xa = x'a$ we deduce that $x = x'$. Therefore there is only one unit element. For if e and e' are unit elements we have $ae' = a = ae$, whence $e' = e$. Similarly there is only one element which is the inverse of a given element. For if a' and a'' are inverses of a , we have $a'a = e = a''a$, and it follows that $a'' = a'$. Notice that e is its own inverse. For if e' is the inverse of e , we have

$$e'e = e = ee$$

and from $e'e = ee$ we deduce $e' = e$.

These are the first fundamental theorems which follow from the axioms 1-4, namely :

Theorem 1. There is a unique unit element and $ae = ea = a$, where a is any element in the group.

Theorem 2. Each element a , has a unique inverse a^{-1} , and $aa^{-1} = a^{-1}a = e$.

The systematic study of abstract groups may be said to have been originated by L. E. Dickson ("Definition of a group and a field by independent postulates," *Trans. American Math. Soc.*, 1905, 198-204). Dickson's axioms were the forerunners of a great variety of axioms for groups and other algebraic systems (rings, fields, etc.). A. Speiser's *Theorie der Gruppen von endlicher Ordnung*, Berlin (1927), and B. L. van der Waerden's *Moderne Algebra*, Berlin (1930), are two of the best books on these matters.

ASTRONOMY. By R. W. WRIGLEY, M.A., F.R.S.E., Royal Observatory, Edinburgh.

THE STARS NEAREST TO THE SUN.—The stars in our own neighbourhood offer an opportunity for intensive study of a sample of the sidereal universe, and, though the sample may not be absolutely typical of the whole, yet a complete knowledge of the contents of

the sphere which has the sun as centre and a radius of 10 parsecs must obviously be most valuable and suggestive. At present such knowledge is not quite within our reach. In the *Astronomical Journal*, No. 1066, Louise F. Jenkins gives a list of the 127 stars, which, with their companions, are known to be situated in this sphere. She has arranged them in order of distance, and tabulates the parallax, absolute magnitude, proper motion, and radial velocity of each star. A short inspection of the table suggests that these 127 stars cannot represent the complete contents of the sphere, for they show no sign of the uniform distribution which would naturally be expected. If the whole sphere be divided into a central portion and nine concentric shells, all of equal volume, the number of stars in each varies considerably, as appears from the following table :

Limits of Parallax.	No. of Stars.
Exceeding 0".215	26
0".215 to 0".171	17
0".170 „ 0".150	14
0".149 „ 0".136	11
0".135 0".126	16
0".125 0".119	8
0".118 0".113	10
0".112 0".108	7
0".107 0".104	11
0".103 0".100	7

Thus, if the distribution in the central portion were maintained throughout, the total number of stars would be doubled, while there are also inequalities in different regions of the central portion itself. Further, of the stars nearer than 5 parsecs, 64 per cent. are fainter than absolute magnitude 10, while, if the distance be doubled, the percentage of faint stars falls to 36. There seems no doubt, therefore, that many stars in our neighbourhood have escaped detection, and Miss Jenkins estimates that less than one-fourth of the stars actually within 10 parsecs of the sun have been included in her catalogue.

Of the 127 stars 25 are binaries, giving the high ratio of nearly 20 per cent. Over the whole sky, one star in nine of those visible to the naked eye and only one in eighteen if stars down to the ninth magnitude are included appears as a visual double, for naturally a more distant system can only be recognised as double if the components are more widely separated.

The table shows an enormous range of luminosity in the 127 stars. Vega, of spectral type A0, is the most brilliant, and emits 2,500,000 times as much light as the M6 star, Wolf 359, whose absolute magnitude is only 16.5. There are no stars in the list of spectral classes O and B, and the only other of type A0 is Sirius. With four exceptions, all the stars follow the main sequence. These

four comprise Pollux which is a K-type giant ; van Maanen's star, which is one of the smallest known and has a volume comparable to that of the earth ; and the companions of Sirius and θ^2 Eridani. The last three are all white dwarfs. Of the 127 stars in the table only 20 are intrinsically brighter than the sun, which therefore may be taken as larger and more brilliant than the great majority of the ordinary inhabitants of space.

We have, indeed, no evidence against the existence in space of very faint stars in very large numbers, and it is quite possible that some of these may be in the sun's near vicinity. Ever since the discovery of Proxima Centauri by Innes in 1915 speculation has been rife regarding the possible presence of one or more of such stars, which must necessarily be very faint. In his Presidential Address to the Astronomical Society of South Africa (*Journal of Ast. Soc. of S.A.*, 4, 59), Dr. John Jackson made some suggestions regarding this possibility. Any star with one-hundredth of the brightness of the sun and parallax $1''$ would be easily visible to the naked eye, and would surely have been detected ere now. If a star at that distance were a binary with mass similar to that of the sun the period of the system would be only one year for an apparent separation of $1''$, and only 12 years for a separation of $5''$. Its nearness would therefore be indicated by the orbital motion. It seems, therefore, that any star nearer than Proxima must be single, one thousand times less luminous than the sun, and probably moving through space with a similar parallel velocity, thus showing practically no proper motion. Such a star might be very difficult to detect. If the sun had a companion accompanying it, as Proxima accompanies α Centauri, it would have a parallax of $20''$, and would probably have been found long ago. Even if it were nearly 200 times fainter than the exceptional star Wolf 359 it would still be of apparent magnitude 12, and therefore readily visible on photographic plates. Dr. Jackson points out that an absolutely dark star within a few thousand astronomical units of our system could not infallibly be detected by its gravitational attraction. Even if near enough to have a parallax of $100''$ and comparable in mass with the sun it would produce no perceptible perturbations in the solar system, while its influence on the sun itself could not be distinguished from the well-known solar motion. His conclusion is that any unknown near neighbour of the sun must be intrinsically very faint, its mass may be anything, and the only method of discovering it is by a comparison of photographs by which its unusual nature may be revealed.

Another near neighbour of the sun, discovered by W. J. Luyten

since the publication of Miss Jenkins' list, is announced in the *Astronomical Journal*, No. 1070. It is a very faint star, with a proper motion of $3''.27$. The material as yet available is insufficient for a reliable determination of the parallax, and the value obtained, $0''.53$, will probably need some modification. If, however, it is correct, and assuming that it is a red star, the absolute visual magnitude must be about 16, placing it among the faintest stars known, and very little, if any, brighter than Wolf 359.

THE LUNAR CRATERS.—Various explanations have been suggested for the strange appearance of the surface of the moon, with its level areas or "maria," its jagged mountain ranges, and, most remarkable and conspicuous of all, its thousands of "craters," ranging in size from great walled plains nearly 150 miles in diameter to small pits scarcely visible to powerful telescopes. The name "crater" at once suggests an analogy with terrestrial volcanoes, but the larger lunar formations are immense by comparison, their floors are beneath instead of above the level of the surrounding country, high mountain peaks often appear in the centres, and smaller craters are frequently superposed on the interiors or walls of the larger ones. After allowing for the small surface gravity on the moon, the disparity in size between say Clavius and Vesuvius is still sufficient to be a serious objection to the volcanic theory of origin. The alternative suggestion that the craters have been produced by the impacts of meteorites has received considerable support. Similar formations on a small scale have been artificially obtained in various ways, possibly the earliest by Robert Hooke when he dropped bullets on to wet tobacco-pipe clay. The chief objection to the theory has been that the craters are circular and not elliptical, it being argued that the former could be produced only by meteors falling perpendicularly, whereas the vast majority would make an oblique impact. N. S. Shaler took the view that the impact of a meteorite on the lunar surface could produce heat enough to liquefy a large area, which, on solidification, would form an extensive dark-coloured level plain, obliterating the original surface features. He, therefore, considered the maria, not the craters, to have a meteoritic origin.

In *Scientia*, 1930, August, A. C. Gifford strongly maintains that meteorites are also responsible for the craters. He points out that the famous Meteor Crater near Cañon Diablo in Arizona, and the more recent fall in Siberia on June 30, 1908, show that large masses are still traversing neighbouring space, and, according to the Planetesimal Theory of the origin of the Solar System, must have been much more numerous in earlier days. The violent impact of these

masses on the surface of the moon, unprotected by any atmospheric envelope, would release energy sufficient not only to liquefy but to vaporise both themselves and the adjacent matter of the moon's surface. The resulting terrific explosion would drive most of the material horizontally, thus forming the crater wall, while the matter which was hurled vertically upwards would eventually fall back and form a central peak. On this theory oblique impacts as well as perpendicular ones would produce circular craters. Gifford calculated the energy of a meteorite travelling at a speed of 20 miles a second to be over one hundred times that of an equal mass of dynamite, and, assuming the amount of material scattered by the explosion to be 50,000 times the mass of the meteorite, he showed the possibility of a resulting crater of diameter comparable with those actually observed on the moon. Such an explosion would reduce much of the material to a white powder, which would account for the whiteness observed on many craters, whereas a dark surface would be produced by the solidification of the material which had merely been reduced to a molten state. The bright streaks radiating from Tycho and some other craters were explained on the assumption that the lunar crust was cracked, allowing molten matter from the interior to be driven through to the surface where it solidified in a crystalline form.

Gifford's theory has received support from the discovery of further terrestrial meteorite craters at Henbury in Central Australia in 1931, and at Wabar in Arabia in 1932, for these formations have clearly been produced by gaseous explosions, and not by the force of simple impact. In *Nature*, 139, 655, Dr. L. J. Spencer discusses the bearing of these new discoveries on the lunar problem. From an examination of materials collected at Wabar it is clear that the heat generated at the impact of the meteorite not only melted the desert sand into a silica glass but actually vaporised it. The meteoritic iron, also largely vaporised, condensed in minute spheres which are preserved in the bubbly silica glass, and show a bright and highly polished surface, suggesting that the earth's atmosphere was temporarily blown aside by the explosion. Spencer suggests that these tiny spheres of shining condensed metal may be the cause of the bright streaks radiating from Tycho, for the low force of gravity on the moon would permit their projection for comparatively great distances. It is interesting that the ratio of the number of craters showing bright rays to those without them is of the same order as the ratio of metallic and purely stony meteorites which reach the earth.

Spencer considers that the lunar mountain ranges were formed

by orustal movements following shrinkage, that the represent lava fields of basic lava from fissure eruptions, and that the various craters belong to different periods in the moon's history, the earlier ones being occasionally engulfed by lava flows. Though the absence of air and water on the moon prohibits denudation, the sudden changes of temperature and the length of the lunar day and night must produce considerable cleavage and weathering of the rocks.

Possibly the strongest argument against the meteoritic origin of the craters is that, to our knowledge, no new ones have been formed since intensive study of the moon's surface began. Many millions of meteors plunge daily into the atmosphere of the earth, and presumably similar numbers fall on the moon. They are, of course, small bodies, and the average number collected each year on the surface of the earth is only five, but these must originally have been much larger in view of the enormous wastage in their passage through our atmosphere. It is certainly strange that no changes, with the possible exception of variations in the size and brightness of the small crater Linné, have been observed on the moon. Spencer considers that in earlier periods the meteoritic bombardment of both moon and earth must have been much more intense, and that the larger stray masses of the solar system have already been gathered up, but, nevertheless, the absence of any definite changes is a point that has not yet been satisfactorily explained.

THE FATE OF COMET BIELA.—An example of the destructive power of a meteor shower is afforded by the history of the periodic comet Biela. This comet, already observed in 1772 and 1805, was recognised in 1826 to have a period of nearly seven years, and an orbit almost cutting that of the earth. Its return in 1832 was strictly according to prediction, but its position in 1839 was unfavourable and it was not seen in that year. At the 1845-46 return the comet was, to the surprise of all observers, found to have split into two parts which were gradually separating. In 1852 the two components were about 1,500,000 miles apart and moved in similar orbits, and this was the last occasion on which either was seen, though diligent search was made in 1859 and 1866. In 1872, although its calculated path came very near the earth, the comet again remained invisible, but its place was taken by a magnificent shower of meteors, which was repeated in 1885, and again, though greatly reduced in numbers, in 1892 and 1899. The twin comets have never reappeared.

Following a suggestion by C. Bruhns in 1867 that the disintegration and ultimate disappearance of the comet might be due

to a collision with the famous Leonid meteor stream, J. Bosler and H. Roure (*Journal des Observateurs*, 1937, Juillet) have calculated the two orbits for the beginning of January 1846, when many observers first saw the comet as double. By successive approximations they arrive at the conclusion that on January 6, 1846, the orbits were only 0.026 astronomical units apart, the radius vector of the comet being 1.021, and that of the meteor orbit 0.994. Allowing for an unavoidable lack of precision in the orbit of the Leonids even after the perturbations due to the major planets have been taken into account, the evidence for a collision exactly at the time when the comet split into two is very strong. At each of its successive returns it would have to encounter the Leonids again, and this provides an explanation for its ultimate complete disappearance.

PHYSICS. By F. C. CHALKLIN, D.Sc., and F. A. VICK, Ph.D., University College, London.

ABSORPTION SPECTRA IN THE VERY SOFT X-RAY REGION (DR. F. C. CHALKLIN).

THE values of the energy levels near the surface of the atom are, for the most part, obtained from ordinary X-ray data. The measurement of the wave-length of an X-ray absorption edge permits the calculation of the energy of some "deep" level, and the estimation of a "shallow" level is made by subtracting from this the energy corresponding to the appropriate X-ray emission line. A subtraction process of this nature will naturally yield a result with a percentage error which may be far in excess of those of the two measurements used. It is therefore very desirable that direct determinations of these levels should be made. This calls for the measurement of absorption-edges in the soft X-ray region, especially above about 50 Å.

The general methods of soft X-ray spectroscopy are fairly well known. Vacuum spectrographs, with plane or concave gratings in the grazing incidence position, are employed. Wave-lengths may be readily determined by comparison with lines from the vacuum spark. The vacuum spark is produced between two electrodes rather less than 1 mm. apart in a high vacuum. A condenser is connected in parallel with this spark gap, and is charged to a high voltage by, for example, a transformer and rectifier. When the potential drop across the spark gap is sufficient, electrons are dragged from one of the electrodes, metal is vaporised, and the condenser discharges a heavy current through the volatilised metal. The magnitude of the current is such that many of the metal vapour atoms are in a high state of ionisation, and radiations therefore occur

in the extreme ultra-violet region of the spectrum. Edlén and Tyrén (*Zeits. für Physik*, **101**, 206, 1936), for example, have obtained, for chromium which has been deprived of fourteen electrons, a line of wave-length as low as 18.5 Å. The wave-lengths of a number of these lines have been evaluated by comparison in high orders with the spectrum of the iron arc.

Absorption work in this region is, however, beset by three great difficulties. Firstly, the continuous X-ray spectrum, the most convenient source, is very weak. Secondly, absorption coefficients for such long wave-lengths are high, necessitating the use of very thin absorbing sheets. Thirdly, photographic photometry in this region is very troublesome. It is only recently that these difficulties have been overcome.

Sanner (*Zeits. für Physik*, **94**, 523, 1935), overcame the difficulty of the weak source by employing, not the continuous X-radiation, but the vacuum spark spectrum of copper. This is very rich in lines in the soft X-ray region and is equivalent to a continuous spectrum of irregular intensity. The absorption of aluminium was studied for a sheet of thickness 5×10^{-5} cm. In experiments on magnesium and selenium he found it convenient to distil these metals on to similar aluminium sheets, and, since the absorption edges examined were at wave-lengths greater than that at which the aluminium L absorption sets in, the aluminium here was comparatively transparent. On the same photographic plate he obtained both a direct spectrum and a spectrum taken through the absorbing substance. A comparison of the two spectra shows clearly the point at which absorption suddenly increases. He measured the L_{III} edges of Al (170.56 Å.) and of Mg (250.25 Å.) and the M_V edge of Se (227.76 Å.). For Al_2O_3 he found the L edge more diffuse than for the metal and its wave-length appreciably diminished. A complex structure was observed for Se.

O'Bryan (*Phys. Rev.*, **49**, 879 and 944, 1936), using the vacuum spark as source, has compared the spectrum taken through celluloid on to which an absorbing film had been deposited, with the spectrum taken through celluloid alone. He has examined lithium and various lithium halides, has found that the structure of the K absorption discontinuity is not simple and that it is affected considerably by chemical combination. Magnesium and its halides have also been examined.

The third problem, that of photometry, has been attacked by Skinner and Johnston (*Nature*, **137**, 826, 1936 and *Proc. Roy. Soc., A.*, **161**, 420, 1937). They are interested in making a detailed examination of the structure near the absorption edges. The study,

by various workers, of the subsidiary absorption phenomena which accompany hard X-ray absorption edges has proved of considerable importance in the elucidation of the behaviour of high energy electrons in the absorbing crystals. By studying the structure for soft X-ray edges greater resolution is obtainable. Skinner and Johnston make their absorbing films by a modification of the method of Lark-Horovitz, Howe and Purcell (*Rev. Sci. Inst.*, **6**, 401, 1935). A sheet of naphthalene has one surface covered with a film of celluloid 40 Å. thick. It is placed in a vacuum and cooled with liquid air. The metal film is distilled on to it. The naphthalene is then allowed to warm up, and, subliming, is pumped off. The vacuum spark is again used as source, but, to obtain precise information of the way in which absorption changes with changing wave-length, it is clearly necessary to adopt some procedure which will remove, on the final curve, the irregularities of the intensity curve of the source. To this end a calculation of the relative absorption coefficient as a function of wave-length is necessary. It is, in fact, necessary to obtain $\log I_0/I_1 (= \mu t)$, where I_0 and I_1 are respectively the intensities of the incident and transmitted beams. A curve connecting $\log I$ with the corresponding microphotometer deflection x must be obtained. Having found the experimental conditions which yield constant relative intensities of the lines in the spectrum, two exposures are taken, one without and one with the absorbing screen. The plates are photometered and for each line are obtained deflections x_0 and x_1 corresponding to I_0 and I_1 . Now $\log I_0/I_1$ varies, in general, only slowly with λ , and consequently, a set of values can be taken for which $\log I_0 - \log I_1$ is nearly constant and subject only to a systematic variation. Using this fact, an $(x, \log I)$ curve is built up in steps from the pairs of values, the scale of $\log I$ being arbitrary. In practice, to render I_1 and I_0 comparable, the exposure through the screen is many times greater than the direct one, so that I_1 is actually increased by a constant factor. Correction is made for the background density. There is no evidence that the plate calibration curve so obtained depends on the wave-length. With the aid of such a curve it is possible to plot μ (in arbitrary units) against the wave-length. The irregularities of the photometer curve of the original emission spectrum are removed and the forms of the curves are consistent.

The K edge of lithium, the L edges of magnesium, and the $M_{II,III}$ edges of nickel and copper have been measured. The L_{II} and L_{III} edges of Mg, separated by only 0.3 volt, are clearly resolved. It may be noted that the values obtained for the edges show appreciable differences from the standard listed values of the

energy levels concerned. Many interesting structure features are pointed out. The three main discontinuities observed for lithium appear to agree with those found by O'Bryan. There is also agreement between the absorption curve for this metal and the excitation curve obtained by Skinner (*Proc. Roy. Soc., A.*, **135**, 84, 1932), by the photo-electric method.

CONTACT POTENTIALS (DR. F. A. VICK).

NINETY-SEVEN years after contact potentials were discovered by Volta, Lord Kelvin (*Phil. Mag.*, **46**, 82, 1898), wrote as follows: "When dry and polished discs of zinc and copper are metallically connected and held parallel, their opposed faces are oppositely electrified, the zinc with vitreous electricity and the copper with resinous electricity, in quantities varying inversely as the distance between them when this is small compared with the diameter of each." In other words, the contact potential difference between two particular surfaces is constant. But Kelvin goes on to say "if the surface of either the copper or the zinc is oxidised or tarnished in any way, notably different results are found . . ." It is this difficulty of obtaining perfectly clean and reproducible surfaces which prevented for many years consistent results being recorded, and led to a long warfare between opposing schools of thought over the origins of contact potential differences. Even if a surface looks clean, there is probably an "adsorbed gas layer" which profoundly modifies the surface forces. The importance of these gas layers is well brought out in the relation (O. W. Richardson, *Phil. Mag.*, **23**, 265, 1912; *Emission of Electricity from Hot Bodies*, p. 39, 1916)

$$eV_{12} = \chi_1 - \chi_2 + eP_{12} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where e is the electronic charge, V_{12} the contact P.D. between surfaces 1 and 2, χ_1 and χ_2 are the corresponding work functions defined by Richardson's equation for thermionic emission

$$i = AT^2 e^{-\chi/kT} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

in which $A = 120\rho\bar{D}$, ρ being the "roughness factor" (1.3-1.5 for most pure metals), \bar{D} the "transmission coefficient (less than 1), T the absolute temperature, and k Boltzmann's constant. P_{12} is the Peltier coefficient and is usually negligible compared with the difference in work functions, so that to a first approximation, if χ_1 and χ_2 are measured in volts

$$V_{12} = \chi_1 - \chi_2 \quad . \quad . \quad . \quad . \quad . \quad (3)$$

and it is well known that the deposition of a monomolecular film on a metal may alter χ by as much as 3 volts. Even without gas layers, inconsistent results may be obtained owing to differences of

surface structure in the metals used at different times. In this connection the measurements of B. A. Rose (*Phys. Rev.*, **44**, 585, 1933) are of interest. He used Kelvin's null method to determine the contact P.D. between the (111) and (100) faces of copper single crystals at different stages of outgassing. The two crystals were mounted opposite and parallel to one another on frames in a pyrex glass tube so that their distances apart could be varied. The pyrex tube was connected to an ionisation gauge and evacuated by diffusion pumps with the usual precautions of liquid air traps, baking of glass, etc. The copper crystals could be outgassed by heating by electron bombardment from neighbouring filaments. It was found that the contact P.D. between the two surfaces rose rapidly at first during the outgassing, passed a maximum and then fell slightly to a steady value. It is probable that the outgassing was never complete and also that stray facets appeared in the crystal surfaces during the long heating, but it seems clear that the contact P.D. between the (111) and (100) faces of copper is greater than 0.46 volt, the (111) face being positive. The value between polycrystalline faces of copper was less than 0.01 volt.

K. T. Compton and I. Langmuir have pointed out (*Rev. Mod. Phys.*, **2**, 145, 1930) that equation (1) may not hold for surfaces which are not homogeneous, either due to difference in structure or to partial covering with surface films, because contact P.D. measurements yield an average value for each surface, while thermionic work functions found in the usual way depend mainly on the most electropositive parts. This is not as serious as it sounds, for when adsorbed films on the surface are not too dilute, the surface fields are found to overlap sufficiently for χ to be an average value. It does emphasise, however, the care which must be taken in applying experimental values to equation (1). Measurements with clean metal surfaces (*e.g.* C. W. Oatley, *Proc. Roy. Soc.*, **155**, 218, 1936) whose work functions are known with sufficient accuracy, have verified this equation.

Recent work has had a different orientation. Equation (1) has been accepted and applied to a determination of χ_1 from measurements of V_{11} , χ_1 being known. This is of particular value in the case of adsorbed films, whether of gases or of alkali metals. To determine χ thermionically it is necessary to measure thermionic emissions i at a series of high temperatures T and plot $\log (i/T^2)$ against $1/T$. But the number of adsorbed atoms on the surface is, in general, dependent on the temperature, so the measurements at different temperatures may be for different surface conditions. Even if the resulting plot of $\log (i/T^2)$ is straight, as Kingdon

found for oxygen on tungsten (K. H. Kingdon, *Phys. Rev.*, **24**, 510, 1924) it has been shown recently (M. C. Johnson and F. A. Vick, *Proc. Roy. Soc.*, **158**, 55, 1937) that the slope of the line may be far from giving χ . In theory, χ can be determined photoelectrically, but in practice the photoelectric threshold is often inconveniently far in the ultra-violet.

Contact potential measurement, then, is the most convenient method of determining χ for surfaces with adsorbed layers of definite constitution, and considerable progress has been made in this direction in recent years. The original Kelvin method is not much used for this purpose, but advantage is taken of the fact that when electrons from a heated cathode pass to a collecting anode, the anode current for non-saturation conditions is a function of the *total* potential difference V_a between cathode and anode. Thus if V_e is the (external) applied P.D. and V_T is a correction term for initial velocities (dependent only on cathode temperature)

$$i = f(V_a) = f(V_e + V_{12} + V_T).$$

Hence, if i is plotted against applied V_e and then the surface of either the cathode or anode is altered, the new $i - V_e$ characteristic is displaced parallel to the old along the voltage axis by an amount equal to the change in contact P.D. Mönch (*Z. f. Phys.*, **65**, 233, 1930) has shown by direct comparison that the measurements of contact P.D. by this method agree with those by Kelvin's method. In practically every case, tungsten has been used for the standard χ_1 , since its work function is known with greatest accuracy and its surface can be cleaned from contaminants by "flashing" at high temperatures.

O. W. Richardson and F. S. Robertson (*Phil. Mag.*, **43**, 557, 1922), I. Langmuir and K. H. Kingdon (*Phys. Rev.*, **34**, 129, 1929) bring about the changes in contact P.D. by altering the nature of the cathode, but it seems best to alter the anode because it is kept at a low temperature during measurements and because changes in cathode surface are likely to alter the shape of the characteristic curves and make the shift of the curve difficult to measure. Various modifications of the electron stream method have been made since Langmuir and Kingdon's experiments.

P. A. Anderson (*Phys. Rev.*, **47**, 958, 1935) projected from an "electron gun" a beam of electrons of energy 4-8 e.v. on to a small region near the centre of a tungsten strip, and plotted the current to the strip as a function of the (external) retarding P.D. applied between strip and electron source. A *thick* layer of barium was deposited on the strip, taking care not to contaminate other

metal surfaces and to keep the amount of impurities such as oxygen very low by attention to vacuum technique. From the shift of the curve, $V_{12} = 2.13$ volts, giving χ for Ba as $4.54 - 2.13 = 2.41$ volts, whereas that from thermionic data is 2.11 (Reimann, *Thermionic Emission*, p. 81, 1934). This arrangement had the advantage of using electrons of low velocity and a small sharply-defined anode surface, but there was a fair amount of metal (and mica) in the tube which may have acted as sources of impurities.

A. L. Reimann (*Phil. Mag.*, **20**, 594, 1935) used the same method as Langmuir and Kingdon, but with a much simpler tube in which the only metal parts were two tungsten filaments, one as cathode and the other as anode, the centres of the filaments being closer together than the ends. After the tube had been baked, etc., the two filaments were "flashed" to clean them. With the cold filament B as anode and hot filament A as source, the $i - V_e$ characteristic was plotted, and then an adsorbed film of oxygen deposited on B (oxygen being removed from A by flashing). The new $i - V_e$ characteristic was parallel to the first and 1.7 volts away, giving the work function of a film of oxygen on tungsten as $4.54 + 1.7 = 6.2(4)$ volts. This is certainly the most accurate determination of this work function so far made, but it is probably a little low since filament B may have been contaminated by migration of oxygen from the leads when it was supposed to be clean. Reimann was able to detect evaporation of oxygen from tungsten at 1300° K.

C. W. Oatley (*Proc. Roy. Soc.*, **155**, 218, 1936), has used an application of A. W. Hull's magnetron (*Phys. Rev.*, **18**, 31, 1921). If a magnetic field of increasing intensity is applied parallel to the axis of a cylindrical diode, then owing to curvature of electron paths, the anode current i will fall to zero at a critical field. Let H_0 be the field for the current to fall to half value, then

$$V_a = \frac{H_0^2 R^2 e}{8m}$$

where R = anode radius. But $V_a = V_{12} + V_e + V_T$, and if V_T is calculated, V_{12} between tungsten filament and anode material is determined. In practice I_0^2 was plotted against V_e to give a straight line whose intercept is $-(V_{12} + V_T)$, where I_0 is the current in the Helmholtz coils to give H_0 for the particular V_a . The effect of slight asymmetry in geometry of the diode was investigated. Copper guard rings were used, but unfortunately these could not be outgassed properly and it is improbable that the anode was really gas free. However, the results for a molybdenum anode

were sufficiently good to show the practicability of the method and to verify equation (1), since χ for molybdenum is known (Du Bridge and Roehr, *Phys. Rev.*, **42**, 52, 1932). Preliminary results for zinc and platinum also are given.

D. B. Langmuir (*Phys. Rev.*, **49**, 428, 1936) uses the same method as Langmuir and Kingdon but reduces the sources of contamination by depositing tantalum anodes and guard rings on the walls of his tube by evaporation from a tantalum filament. Currents between the test filament and tantalum filament were used to study (a) the variation of work function with "activation" of a thoriated tungsten filament, and (b) the change of work function with temperature of thoriated tungsten and pure tungsten.

We now have an interesting series of papers by Bosworth and Rideal (R. C. L. Bosworth, *Proc. Camb. Phil. Soc.*, **33**, 394, July 1937; *Proc. Roy. Soc.*, **162**, 32, Sept. 1937; R. C. L. Bosworth and E. K. Rideal, *Proc. Roy. Soc.*, **162**, 1, Sept. 1937). In their method a vertical tungsten strip acts as anode, the source filament being in front of it and skew so that their centres clear by a few millimetres only. The measured current then flows from a small length of the source filament to the centre of the strip. By suitable ovens, etc., thin films of sodium, potassium, hydrogen or oxygen (or mixtures of these), can be deposited on the strip. The contact potentials are deduced from the shift of $i - V_e$ characteristics in the usual way. A good deal of useful information on surface films has resulted from their measurements. For example, a nearly full monomolecular layer of hydrogen on tungsten has thermionic constants $\chi = 5.60$ volts, $A = 30$ amps/cm.²/deg.². A film of deuterium on tungsten is 20 millivolts positive with respect to a similar hydrogen film. The condensation coefficient of hydrogen on cold tungsten is 0.01. The effective dipole moment of each hydrogen atom on tungsten is fairly constant at -0.42 Debye unit, but for sodium the moment changes from 22.6 to 5.4 units as θ (fraction of surface covered) increases from 0 to 1. Contact potential differences for potassium on films of oxygen and hydrogen on tungsten were also measured. The χ for sodium on tungsten first falls to a minimum as θ increases and then rises slowly to a steady value. From the rate of change of contact P.D. when the strip is exposed to sodium vapour the vapour pressure of sodium is determined. The evaporation of sodium at various temperatures is studied in detail.

From a general study of recent work on contact potentials we may conclude (1) the conditions for precise determination of contact potentials are just as rigorous as for thermionic measurements;

(2) the simple relation between contact P.D. and work function has been found to hold and is of particular value in the study of adsorbed films ; (3) the electron stream method gives the same results as Kelvin's method and for its use the electron source should be homogeneous, should remain constant during the measurements and should be as nearly as possible equipotential. The experimental tube should be as free as possible from metal or other possible sources of impurities.

GENERAL AND ORGANIC CHEMISTRY. By O. L. BRADY, D.Sc., F.I.C., University College, London.

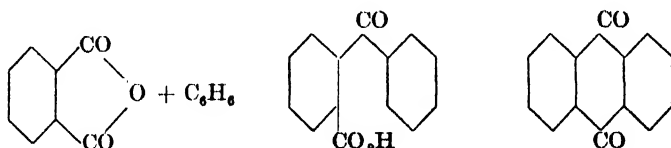
THE output of research in organic chemistry is now enormous and it is not surprising that those who follow the changes in what may be described as the academic aspect of the subject are apt to overlook the corresponding alterations in manufacturing practice. Unfortunately text-books are of little help as even new editions describe at length manufacturing processes which are obsolete and ignore modern methods. The subject is difficult to treat, mere study of the patent literature is not helpful as but few of the patented processes ever reach the production stage and manufacturers are usually unwilling to indicate which processes they are now employing. In this article an attempt is made to outline some of the changes in manufacturing technique. In some cases the new process has almost completely supplanted the old, in others it is rapidly doing so, whilst in others it is only just being adopted. Practice also varies from one country to another, depending on availability of capital for new plant, accessibility of materials and the usual circumstances which condition economic manufacture. An important influence in the development of new methods has been the contributions of engineers in providing plant working at high temperatures and pressures up to 200 atmospheres.

PHTHALIC ANHYDRIDE.—The cheapness of atmospheric oxygen as an oxidising agent has resulted in the extension of its use in conjunction with catalysts. Phthalic anhydride, though not now so much used for the synthesis of indigo, is still an important intermediate and the old method of preparation from naphthalene by oxidation with sulphuric acid has been supplanted by catalytic oxidation at about 425° with air. The catalyst used is vanadium pentoxide alone or mixed with molybdenum oxide and manganese oxide supported on infusorial earth or roughened aluminium turnings, the heat-conducting qualities of the latter being an advantage. Temperature control in the process presents difficulties owing to the large amount of heat generated at a high temperature by the

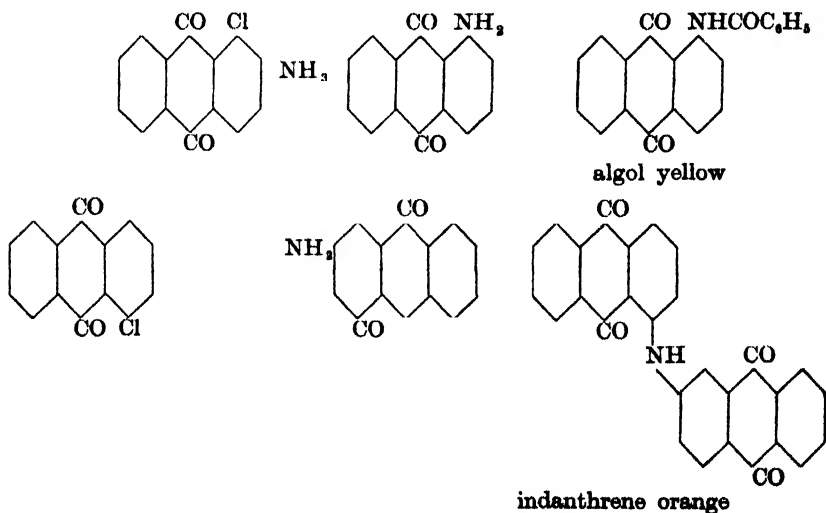
oxidation and the necessity of keeping the catalyst at a fairly uniform temperature. For this reason the initial cooling is performed by the vaporisation of a liquid boiling under a pressure which raises its boiling-point to the optimum catalyst temperature, for example diphenyl, sulphur or naphthalene which subsequently passes into the oxidation chamber.

Phthalic anhydride is now converted into numerous important products by novel processes. Treatment at $210-285^{\circ}$ with steam in the presence of chromium phthalate results in decarboxylation with the formation of benzoic acid which is superior to that prepared by the old process from toluene in that it is free from chlorine.

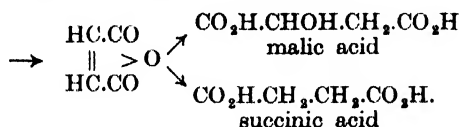
Phthalic anhydride is also employed in the preparation of anthracene derivatives. Anthraquinone is now manufactured by treating phthalic anhydride with benzene in the presence of aluminium chloride and dehydrating the benzoylbenzoic acid formed with concentrated sulphuric acid.



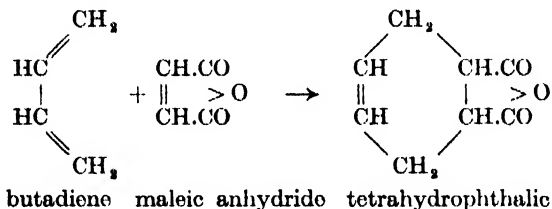
The chloroanthraquinones are made either by using chlorinated phthalic anhydride, chlorobenzene or by chlorinating the benzoyl benzoic acid before ring closure. These compounds are of importance as intermediates for the preparation of derivatives of aminoanthraquinone, an important series of vat dyes of which the following are simple examples :



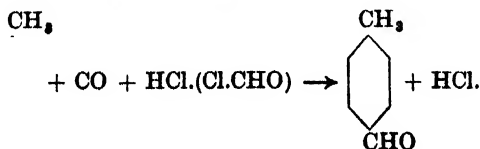
MALEIC ACID.—Benzene is now oxidised to maleic anhydride by air in the presence of vanadium pentoxide.



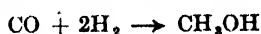
The maleic anhydride can be converted quantitatively to malic acid by heating with water under pressure, and this compound is replacing citric and tartaric acids for many purposes where a weak organic acid is required such as in acid beverages; it may also be reduced by hydrogen, catalytically, to succinic acid used for preparing resins. It is interesting that "common" malic acid is no longer the *lævo*-rotatory compound prepared from natural sources but synthetic racemic malic acid. The price of the optically active form is becoming prohibitive, to the dissatisfaction of workers in the field of optical isomerism who use the acid for resolving racemic bases. Maleic acid may also become of technical importance in connection with the Diels-Alder synthesis.



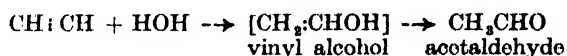
BENZALDEHYDE.—Air oxidation of toluene to benzaldehyde has not proved very successful, but oxidation by means of manganese dioxide and sulphuric acid or by ammonium manganic sulphate prepared by electrolytic oxidation has replaced the old chlorination method since it yields a product free from chlorine, an important consideration if the aldehyde is to be used for flavouring purposes. A more recent method is synthesis from benzene by means of aluminium chloride containing a small percentage of water to generate the necessary hydrogen chloride and carbon monoxide at 90 atmospheres pressure. Substituted benzaldehydes of importance as intermediates, such as *p*-chlorobenzaldehyde and *p*-tolualdehyde, are manufactured in an analogous manner.



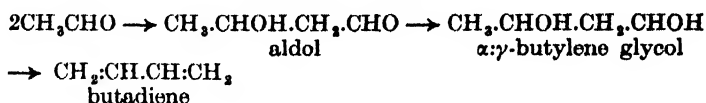
ACETALDEHYDE, ACETIC ACID, ACETONE, ETC.—The commercial production of methyl alcohol by catalytic reduction of carbon monoxide with hydrogen at high pressures



would, in highly industrialised countries at all events, entirely displace wood distillation except that the latter operation produces other useful products such as acetone, acetic acid and charcoal. The ever-increasing demand for acetone, acetic acid, vinyl acetate, etc., in connection with the cellulose ester, varnish and plastic industries has resulted in the synthesis of these compounds on a yet greater scale from calcium carbide. Acetylene from the carbide is converted to acetaldehyde by hydration in the presence of mercury salts



Acetaldehyde is oxidised to acetic acid by air in the presence of manganese acetate as catalyst. Acetic acid vapour passed over calcium or barium oxide on a suitable support at 500° yields acetone. Acetaldehyde can be reduced with hydrogen and nickel catalyst to ethyl alcohol and a considerable amount of this compound is now prepared by this process. Acetaldehyde undergoes the aldol condensation and the aldol on catalytic reduction with hydrogen gives α : γ -butylene glycol which on dehydration yields 1:3-butadiene, a source of some synthetic rubbers.



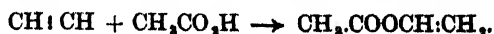
The aldol is dehydrated to crotonaldehyde which is reduced by hydrogen with a copper-nickel catalyst to *n*-butyl alcohol largely used in the preparation of solvents and plasticisers.



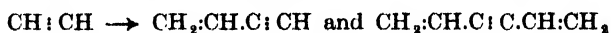
Acetaldehyde gives excellent yields of ethyl acetate by a Cannizzaro reaction when treated with aluminium ethoxide catalyst activated by treatment with a small quantity of, for example, water or tin chloroethoxide.



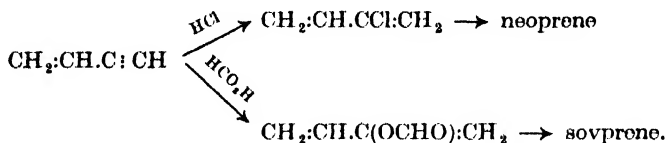
Acetylene passed into acetic acid in the presence of mercury salts gives vinyl-acetate used in the artificial resin industry:



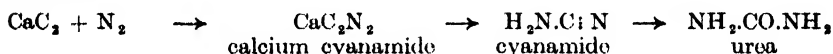
When passed into a solution of cuprous chloride in ammonium chloride acetylene gives vinylacetylene and divinylacetylene.



The former with hydrogen chloride yields chloroprene which polymerises readily to duprene, an important rubber substitute now largely manufactured. With formic acid vinylacetylene gives formoprene which polymerises to sovprene, another rubber substitute manufactured in Russia.



UREA.—Urea is now manufactured in enormous quantities for use as a fertiliser and for the preparation of synthetic resins. Two methods are employed, partial hydrolysis in feebly acid solution of cyanamide prepared from calcium carbide and nitrogen in the electric furnace



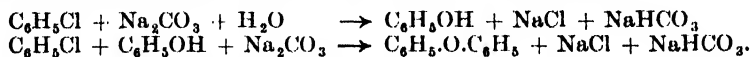
and by the direct union of ammonia and carbon dioxide with the initial production of ammonium carbamate which on heating to 130–150° under 33–35 atmospheres pressure yields urea.



ANILINE.—The large amounts of chlorine available from the alkali industry as a by-product are difficult to dispose of and the successful large-scale synthesis of ammonia by the Haber process has resulted in a change in practice in the manufacture of aniline and some of its derivatives. Nitric acid for the preparation of nitrobenzene is a relatively costly reagent so benzene is first chlorinated and the chlorobenzene heated with 4 to 5 molecular proportions of aqueous ammonia with a small percentage of cuprous oxide or chloride to about 200° in a high-pressure autoclave. About 90 per cent. of the theoretical amount of aniline is formed together with about 1 per cent. of diphenylamine and 5 per cent. of phenol which are easily removed. *p*-Nitraniline is prepared by the action of aqueous ammonia on *p*-nitrochlorobenzene at 170° in an autoclave with an efficient stirring mechanism. Some 4 : 4'-dinitrodiphenylamine is formed at the same time and this impurity is objectionable in the preparation of solutions of the *p*-nitrobenzenediazonium salts used in dyeing as it does not diazotise nor dissolve. Various

methods have been employed for removing it such as crystallising the *p*-nitraniline from ammonia under pressure, the 4 : 4'-dinitrodiphenylamine being soluble in the alkaline medium.

PHENOL.—The old method of manufacturing phenol by fusion of sodium benzenesulphonate with sodium hydroxide is open to many objections among which may be mentioned the weight of raw materials compared with the yield of phenol, consequently the direct hydrolysis of chlorobenzene is making headway as a manufacturing process. Chlorobenzene with aqueous alkalis under suitable conditions gives phenol and some diphenyloxide



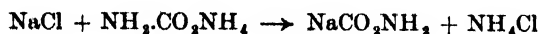
The reaction is brought about by circulating an emulsion of chlorobenzene with 10 per cent. aqueous sodium carbonate at 320° through a copper tubular autoclave, the walls of the vessel acting as a catalyst; 10 per cent. of diphenyl oxide is added to the reaction mixture and it is found that this prevents any further formation of this by-product.

LONG-CHAIN ALCOHOLS.—The sodium salts of the sulphates of long-chain alcohols $\text{CH}_3[\text{CH}_2]_n\text{CH}_2\text{OSO}_3\text{Na}$ have valuable detergent properties and are being increasingly used in place of or mixed with ordinary soaps. Their emulsifying and wetting properties are greater than those of soap, they are equally soluble in hard and soft water and, unlike the soaps, have no tendency to leave a deposit of fatty acid which is difficult to remove, since the alkyl hydrogen sulphates $\text{CH}_3[\text{CH}_2]_n\text{CH}_2\text{OSO}_3\text{H}$ are soluble in water. The consequent demand for the long-chain alcohols has resulted in the application of catalytic reduction to the corresponding acids for their manufacture. Oleic acid when reduced with hydrogen and a zinc-cadmium-copper chromite catalyst at 390–400° under a pressure of 200 atmospheres yields a mixture of oleyl and stearyl alcohols. Under these conditions the carboxyl group is more readily reduced than the double bond. The mixture of alcohols can be subsequently converted to stearyl alcohol by reduction with hydrogen and a nickel catalyst at a low temperature in the usual manner.

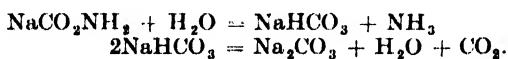
SODIUM CARBONATE.—It appears that a new technique in connection with the manufacture of sodium carbonate is being employed in Japan, the reactions being carried out in liquid ammonia. The process depends upon the solubility of sodium chloride and the insolubility of sodium carbamate in this solvent. Ammonium carbamate is first formed by the action of carbon dioxide on liquid ammonia



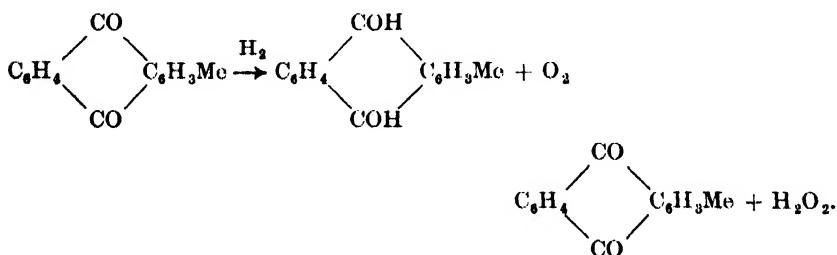
and to this a solution of sodium chloride in liquid ammonia is added when sodium carbamate is precipitated.



The sodium carbamate on treating with steam gives sodium carbonate.



HYDROGEN PEROXIDE.—H. E. Armstrong, many years ago, pointed out that, when organic compounds were oxidised by moist molecular oxygen, hydrogen peroxide was formed. It is now suggested that this phenomenon might be used for the commercial preparation of hydrogen peroxide as conditions have been found under which good yields are obtained (Pat. No. 465,070, 1936). Methyl anthraquinone in benzene and cyclohexanol can be reduced catalytically by hydrogen. The solution after removing the nickel catalyst rapidly absorbs oxygen with the regeneration of methyl anthraquinone and the formation of hydrogen peroxide which can be extracted with water.



The yield of hydrogen peroxide is over 90 per cent. of the oxygen absorbed and the methyl anthraquinone can be again reduced.

The above are but a few examples of the changes in industrial processes that have taken or are taking place. The writer wishes to express his indebtedness to *Unit Processes in Organic Synthesis*, Editor-in-Chief P. H. Groggins (McGraw-Hill Publishing Co. Ltd.) for valuable information on some of the subjects discussed.

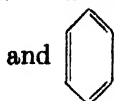
PHYSICAL CHEMISTRY. By H. W. MELVILLE, D.Sc., Ph.D., Colloid Science Laboratory, Cambridge.

PROGRESS in Physical Chemistry is to a large extent dependent upon and intimately concerned with the development of new experimental technique. On the one hand fresh light is brought to bear on problems insoluble with the methods previously at the

chemist's disposal; on the other, new fields of investigation are opened up. In this article two such advances will be described. It is, moreover, interesting to note that both promise to have extensive application in organic chemistry. The first has to do with the precise determination of the heats of hydrogenation of unsaturated organic molecules and the second with the mode of interaction of simple hydrocarbons with catalytic surfaces.

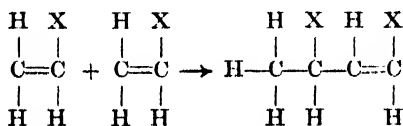
HEATS OF HYDROGENATION.—At a first glance there would seem to be no necessity for the determination of the heat of hydrogenation of unsaturated molecules, for this quantity ($-\Delta H$) might readily be computed from the difference in the heats of combustion of the saturated and unsaturated compounds. As the molecular weight increases, however, the difference in heats of combustion becomes so small as to be useless in determining at all accurately how, for example, the heat of hydrogenation is affected by the structure of the molecule. Another method is to measure the variation of equilibrium constant of the hydrogenation reaction with temperature and calculate the heat content change by means of the usual formula $d \ln K_p / dT = -\Delta H / RT^2$, where K_p is the equilibrium constant, ΔH the heat content change in the reaction, R is the gas constant and T the absolute temperature. One of the difficulties of the method, pronounced with the more complicated molecules, is that no matter from what side the equilibrium is approached, secondary reactions may introduce such complications that ΔH can only be calculated in an approximate manner. The third method consists in measuring the heat of hydrogenation directly in a calorimeter filled with a catalyst to ensure that the reaction will go quantitatively to completion at a reasonably low temperature. For the hydrogenation of ethylene to ethane all three methods gave results in reasonably good agreement having regard to the technique employed, but there were discrepancies which required further investigation. Calculations had also been made of the entropy of the molecules participating in this reaction so that ΔH could be calculated—this revealed further disagreement. (It would be a digression to discuss these matters, but reference may be made to a paper on ethane-ethylene-hydrogen system by Teller and Topley, *J. Chem. Soc.*, 876, 1935.) Hence one necessity for the exact determination of ΔH is evident, namely, to check calculations of the entropy of simple molecules. Another important field of investigation lies in determining how substituents in a double bond compound affect its heat of hydrogenation. Yet another is connected with the phenomenon of resonance. For example, when a molecule such as benzene can be represented (employing ordinary

single and double bonds) by two different structures, namely

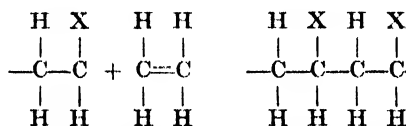


and , then, according to quantum mechanical methods of

molecule building there is a structure intermediate in configuration between the two, possessing a smaller potential energy: this is the normal state of the molecule. Owing to resonance a molecule has less energy than might be expected, thus conferring upon it added stability. Correspondingly, the heat of hydrogenation should differ considerably from that computed on the assumption that the molecule has three double bonds in it. Heats of hydrogenation, if sufficiently accurate, may therefore indicate how much resonance energy is available for stabilisation. Finally, there is a possible application to polymerisation reactions. When derivatives of ethylene polymerise, the essential feature of the reaction is that each time a monomeric molecule adds on to the growing polymer a double bond is replaced by a single bond, thus



or



(X is a substituent, *e.g.* CH₃, Cl, COOH, etc.)

The energy evolved in this reaction, which depends on the heat of hydrogenation of the double bond, may play an important part in facilitating the subsequent addition of the next molecule of monomer (*cf.* Flory, *J. Amer. Chem. Soc.*, **59**, 241, 1937). It is for these reasons that Kistiakowsky and co-workers¹ have embarked on a comprehensive study of the heats of hydrogenation with the calorimetric technique.

THE CALORIMETER.—In order to obtain the necessary precision an elaborate apparatus is required, but space will only permit of a description of the more important parts. The normal procedure

¹ I, Kistiakowski, Romeyn, Ruhoff, Smith and Vaughan, *J. Amer. Chem. Soc.*, **57**, 65, 1935; II, III and IV, Kistiakowski, Ruhoff, Smith and Vaughan, *ibid.*, **57**, 876, 1935; **58**, 137, 1936; V, Dolliver, Gresham, Kistiakowski and Vaughan, *ibid.*, **59**, 831, 1937; Conant and Kistiakowski, *Chem. Reviews*, **20**, 181, 1937.

of admitting the gases to the catalyst and noting the temperature rise of the system after the completion of the reaction, possesses several disadvantages. The introduction of accurately known amounts of the reactants is difficult and the large mass of catalyst necessary introduces the troublesome feature of having to correct the results for the heat change consequent on the adsorption of the several molecules on the catalyst surface. Instead, an adiabatic calorimeter is employed, that is, a calorimeter surrounded by a bath of which the temperature is automatically maintained at the same level as that of the calorimetric liquid itself. For this purpose the calorimeter, filled with diethylene glycol, is suspended within a second container the outer walls of which are surrounded by a 30-litre bath of diethylene glycol which in turn is surrounded by an air thermostat regulated to 0.1° . Besides the multiple junction thermopile to measure the temperature of the calorimeter there is a second pile which controls the heating current of the large bath by a low-lag heater. This is accomplished by connecting the controlling pile to a Moll galvanometer which illuminates a photo-electric cell. When the temperature of the calorimeter rises, the photo cell, by means of a relay, switches on a small auxiliary heater in the large bath. Simultaneously an electric motor is set in motion to increase gradually the main heating current to the large bath. When the auxiliary current is off, the motor is reversed and the main current is gradually decreased. Such a device reduces the lag of the system to a minimum.

The reaction vessel, containing a copper catalyst, is so arranged that a continuous stream of reactants can be sent through from suitable regulators. When the system has attained a steady state, that is, a linear increase of temperature with time, the gases issuing from the catalyst are diverted to a measuring and analytical apparatus for a given period during which the temperature rise is determined. As is customary, the calorimeter is calibrated by supplying a measured number of watts to an internal heating coil. The only slight error that might intrude is the change in the volume of adsorbed gases as the temperature rises, though the magnitude of this effect is probably negligible. The estimated accuracy of the method is about 0.1 per cent., the limiting factor frequently being the degree of purity of the compounds hydrogenated.

THE DATA.—Already the heats of hydrogenation of a great variety of molecules have been determined, but in this review reference will only be made to hydrocarbons to show the scope of the information afforded by the data. That important constitutive effects are obtained is evident from the fact that the heat of

hydrogenation of ethylene is 32.8 k. cal. whereas that of tetramethyl ethylene has dropped by no less than 6.2 k. cal. Confining attention to the monosubstituted derivatives it will be observed from the results set out in the table that the value of ΔH is prac-

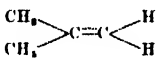
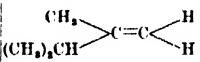
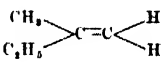
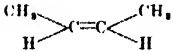
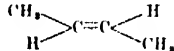
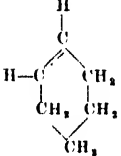
MONOSUBSTITUTED ETHYLENES

— ΔH for ethylene 32.8 k. cal. at 355° K.

Substituent.	CH_3	C_2H_5	$n\text{C}_4\text{H}_9$	$(\text{CH}_3)_2\text{CH}$	$(\text{CH}_3)_3\text{C}$
— ΔH	30.1	30.3	30.1	30.3	30.3

tically independent of the nature of the substituent, although there is a considerable change from ethylene itself. Thus the important factor is the substitution of an alkyl group for the hydrogen atom.

DISUBSTITUTED ETHYLENES

Compound.			
— ΔH (355° K)	28.4	28.0	28.5
Compound.			
— ΔH (355° K)	28.6	27.6	28.6

With the di-substituted ethylenes there is a further drop in the value of $-\Delta H$, as might be anticipated, the increment being nearly the same as that for the substitution of the first methyl group. Again there is the same regularity, namely the predominant effect of the introduction of an alkyl group, there being no significant difference whether the asymmetrical or the *cis* molecule is hydrogenated. The substitution of a third and a fourth methyl group in trimethyl ethylene ($-\Delta H = 26.9$) and in tetramethyl ethylene ($-\Delta H$, 26.6 k. cal.) changes ΔH by progressively decreasing amount. In conformity with these regularities it would be expected that ΔH for cyclohexene would be similar to *cis* butene-2, as indeed is the case ($-\Delta H$, 28.6).

In the diene series the interest lies not only in determining the total heat of hydrogenation but also the heat of hydrogenation of

the various possible isomers which can be formed by the addition of one molecule of hydrogen. This first heat of hydrogenation cannot, of course, be determined directly. It is therefore calculated from the total heat of hydrogenation and from the value of ΔH for the hydrogenation product. If the latter has not been determined it may be readily calculated from the regularities exhibited by the ethylene derivatives. Allene is placed in a class by itself, $-\Delta H$ for hydrogenation to propylene being larger than any other compound, viz. 41.2 which is 11 k. cal. greater than that for any asymmetric derivative.

DIENES

Compound.	Mode of Addition.	Product.	$-\Delta H$ (355° K).
$\text{CH}_2=\text{CH}-\text{CH}=\text{CH}_2$	1,4	$\text{CH}_3-\text{CH}=\text{CH}-\text{CH}_3$ (cis)	28.5
	1,4	$\text{CH}_3.\text{CH}=\text{CH}-\text{CH}_3$ (trans)	29.5
$\text{CH}_2=\text{C}(\text{CH}_3)-\text{C}(\text{CH}_3)=\text{CH}_2$	1,2	$\text{CH}_3.\text{CH}_2.\text{CH}=\text{CH}_2$	26.8
	1,4	$(\text{CH}_3)_2.\text{C}=\text{C}(\text{CH}_3)_2$	27.3
	1,2	$(\text{CH}_3)_2.\text{CH}.\text{C}=\text{CH}_2$	25.9
$\text{CH}_3.\text{CH}=\text{CH}-\text{CH}=\text{CH}_2$	1,4	$\text{CH}_3.\text{CH}_2.\text{CH}=\text{CH}.\text{CH}_3$ (cis)	25.5
	1,4	$\text{CH}_3.\text{CH}_2.\text{CH}=\text{CH}.\text{CH}_3$ (trans)	26.5
$\text{CH}=\text{CH}-\text{CH}=\text{CH}$ $\text{CH}_2 \quad \quad \quad \text{CH}_2$	3,4	$\text{CH}_3.\text{CH}_2.\text{CH}_2.\text{CH}=\text{CH}_2$ $\text{CH}_2.\text{CH}=\text{CH}.\text{CH}_2$	23.8 26.8
$\text{CH}=\text{CH}-\text{CH}=\text{CH}$ $\text{CH}_2 \quad \quad \quad \text{CH}_2$ calculated values.		$\text{CH}_3.\text{CH}=\text{CH}.\text{CH}_2$ $\text{CH}_2 \quad \quad \quad \text{CH}_2$	24.0

The first interesting result is the effect of conjugation in reducing the value of $-\Delta H$ by some 2-3 k. cal.—the influence of resonance. As the number of carbon atoms between the double bonds is increased, the value of ΔH approaches that of propylene though even in pentadiene-1,4 ($-\Delta H$, 30.7, 1,4 addition) and hexadiene-1,5 ($-\Delta H$, 30.4) $-\Delta H$ is not quite equal to that for propylene.

With butadiene and pentadiene it will be seen that the 1,4 addition in the trans position is the most likely, if $-\Delta H$ is taken as a measure of the probability of appearance of the appropriate butene and pentene.

The values of $-\Delta H$ in the diene series exhibit the same sort of regularity as is found in the ethylene derivatives. One example

will suffice. A disubstituted compound $R.CH=CH-CH=CH.R$ should differ from butadiene in the value of ΔH to the same extent as $R.CH=CH.R$ differs from ethylene. The estimated value for of $-\Delta H$ for $R.CH=CH-CH=CH.R$ should therefore be $29.5 - 4.5 = 25.0$. This is in reasonable agreement with the value of 26.8 k. cal. for *cyclohexadiene*. Such a regularity is not, however, evident with *cyclopentadiene*. In a similar way it will be seen that the introduction of methyl groups in the 2,3 positions in butadiene decreases the value of $-\Delta H$ in conformity with the effect in ethylene.

One of the most surprising results of these experiments is obtained with cyclic compounds assuming that a six membered ring such as *cyclohexane* is strain-free, whereas five, four and three membered rings are under a progressively increasing strain. The degree of strain may be expressed in calories from combustion data : for *cyclopentane* the strain amounts to 4 k. cal. Now the lower values of $-\Delta H$ for *cyclopentadiene* (24) and *cyclopentene* (26.9) indicate that the strain increases on opening the double bonds. That these figures are in no way due to any peculiarity of the method may be shown from the fact that *cyclohexadiene* and *cyclohexene* exhibit perfectly normal behaviour, their heats of hydrogenation being calculable from the rules already established. These and other similar data are therefore in conflict with accepted views of the structure of cyclic compounds. The explanation of the anomaly is as yet unknown.

INTERACTION OF HYDROCARBONS WITH CATALYSTS.—There is now abundant evidence to support the contention that hydrogen molecules are very readily dissociated to atoms when they are adsorbed on surfaces active as catalysts for hydrogenation. In addition there is a smaller body of evidence to indicate that oxygen molecules, too, may be dissociated on coming into contact with certain solids, such as tungsten, for example. Practically no data, however, exist to show how simple hydrocarbons interact with catalysts. Such information is required for the interpretation of hydrogenation and dehydrogenation reactions, one of the simplest examples being the mechanism of the exchange reactions of deuterium with hydrides. Unfortunately, looking at the matter conversely, the study of the latter reactions does not provide the evidence as to whether or not hydrocarbons are dissociated for the following reason. Consider the reaction $D_2 + CH_4 = CH_3D + HD$, which is known to be catalysed by nickel. Measurement of the velocity of the ortho deuterium conversion, which gives directly the velocity of dissociation of D_2 molecules, proves at once that this is not, in general, the rate determining step in the reaction. Two possibilities remain,

namely that the controlling reaction is either the attack of a molecule of methane adsorbed as such by a deuterium atom— $D(ads.) + CH_4(ads.) = CH_3D(ads.) + H(ads.)$ —or the rate of combination of the deuterium atom with the CH_3 radical produced by dissociation of the CH_4 molecule on the nickel surface. No matter how detailed the investigation of the kinetics is made, no absolutely unambiguous choice can be made between the two mechanisms. The only way of solving the problem is to study the interaction of a mixture of the hydride and deuteride with the surface. If dissociation does occur, molecules of intermediate D-content CH_3D, CH_2D_2, CHD_3 , will appear in the gas mixture. Their presence can, however, only be detected spectroscopically since no other physical method is sufficiently sensitive for the purpose. Experience has shown that although there is usually a considerable difference in the ultraviolet absorption spectra of isotopic molecules, the absorption may lie in an inconvenient region of the spectrum (with methane, in the Schumann ultraviolet), or the vibrational structure may not be sufficiently well defined to serve as an indicator. On the other hand owing to the relatively large change—of the order of 40 per cent.—in vibration frequency brought about by the introduction of deuterium atoms into the molecule and also to the splitting of degenerate energy levels in the molecule, the infra red absorption spectra exhibit striking changes as D-atoms replace H-atoms in the hydride. The technique has been worked out in considerable detail by Benedict, Morikawa, Barnes and Taylor (*J. Chem. Physics.*, **5**, 1, 1937) for the methanes and the ethanes. These hydrocarbons absorb strongly in two regions, for example, with methane at 2000 to 3200 cm^{-1} , owing to valence vibrations and at 1300 to 900 cm^{-1} , owing to deformation vibrations. The latter region is the more convenient for isotopic analysis. The nature of the absorption spectra is shown in Fig. 1 where the absorption coefficient is plotted against reciprocal wavelength for three samples of methane of different D-content. The molecules giving rise to the maxima are indicated in the diagram. Hence by measuring the absorption at any one of these characteristic wavelengths an estimate may be made of the mole fraction of any particular molecule. Further, by a sufficient number of absorption measurements the D-content of the methanes may be calculated. In fact it is even possible to determine whether the mixture of methanes is in equilibrium, a circumstance which allows of the progress of the establishment of equilibrium being followed.

Employing a nickel catalyst, Morikawa, Benedict and Taylor (*J. Amer. Chem. Soc.*, **58**, 1445, 1936) found that CH_4 and CD_4

readily interact to yield the equilibrium amounts of the intermediate methanes, thus demonstrating at once that methane can be chemisorbed to methyl radicals and hydrogen atoms on such a surface. The exchange reaction of deuterium with methane was followed

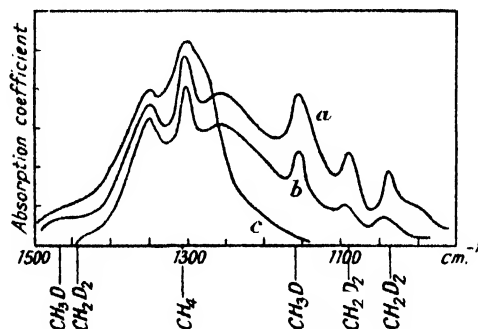


FIG. 1.—Absorption spectra of equilibrium methanes.
 ≈ 180 mm. $a = 18.1$ per cent. D, $b = 9.5$ per cent. D, $c = 0$ per cent. D.

under exactly the same conditions. Although this reaction goes somewhat slower than the $\text{CH}_4 - \text{CD}_4$ reaction, as will be observed from the following results, both possess practically identical temper-

Temp. ° C.	$\text{CH}_4 - \text{CD}_4$ reaction : per cent. conversion per hour.	$\text{CH}_4 - \text{D}_2$ reaction : per cent. conversion per hour.
138	1.1	0.07
184	11.2	8.2
218	60	15.5
255	240	---

ature coefficients giving an apparent energy of activation of 20 k. cal. Unfortunately the para hydrogen conversion or the rate of formation of HD molecules in an $\text{H}_2 - \text{D}_2$ mixture (that is, the rate of dissociation of hydrogen) has not simultaneously been measured, but it is certain in view of the great activity of these bulk catalysts that either reaction would proceed much more quickly than the $\text{CH}_4 - \text{CD}_4$ or the $\text{CH}_4 - \text{D}_2$ reaction in presence of methane. The smaller rate of the $\text{CH}_4 - \text{D}_2$ reaction is probably due to displacement of adsorbed methane by hydrogen. By this technique it is therefore proved conclusively that methane is dissociated on a nickel surface and that in the exchange reaction with deuterium, the rate of dissociation of CH_4 is the controlling factor.

When methane is replaced by ethane and hydrogen is also present in the reaction system, then the ethane may also undergo hydrogenation to methane. The rate of this latter process gives

the velocity of dissociation of ethane to methyl radicals. It has been seen that in the methane deuterium reaction, the rate of exchange affords a measure of the velocity of dissociation of the methane. In a similar manner, the exchange reaction of deuterium with ethane may be followed to obtain the rate of dissociation to $C_2H_5 + H$. Employing the infra red technique, supplemented where necessary by gas analyses, Morikawa, Benedict and Taylor (*J. Amer. Chem. Soc.* **58**, 1795, 1936) have been able to compare the velocities and associated energies of activation of the three processes on a nickel catalyst, namely (a) $CH_4 \rightarrow CH_3 + H$, (b) $C_2H_6 \rightarrow C_2H_5 + H$ and (c) $C_2H_6 \rightarrow 2CH_3$. One or two numerical results may be quoted by way of illustration to show that process (b) occurs more readily than (c) and with a very much smaller energy of activation.

Hydrogenation $C_2H_4 + H_2 = 2CH_4$		Exchange $C_2H_6 + D_2 = C_2H_5D + HD$	
Temp. ° C.	Per cent. C_2H_4 reacted/hour.	Temp. ° C.	C—D bond per cent. equilibrium attained per hour.
157. . . .	4	110. . . .	13
172. . . .	19	138. . . .	ca. 100
184. . . .	73	—	—

As might be expected the corresponding reactions with propane exhibit similar kinetic behaviour, exchange occurring more readily

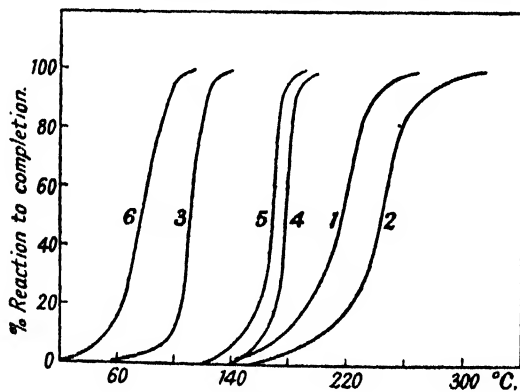
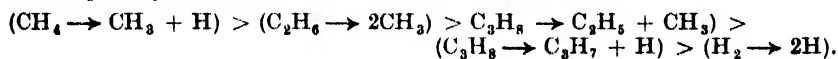


FIG. 2.

Curve.	Reaction.	Time (hours).
1. . . .	$CH_4 + CD_4$, Ex.	1
2. . . .	$CH_4 + D_2$, Ex.	1
3. . . .	$C_2H_6 + D_2$, Ex.	2.5
4. . . .	$C_2H_6 + H_2 \rightarrow 2CH_4$	1
5. . . .	$C_2H_6 + 2H_2 \rightarrow 3CH_4$	1
6. . . .	$C_2H_6 + D_2$, Ex.	1

than hydrogenation to methane and ethane (Morikawa, Trenner and Taylor, *J. Amer. Chem. Soc.*, **59**, 1103, 1937). For example, the exchange reaction goes with a speed similar to that for ethane but at about 40° lower on the temperature scale.

All these results are conveniently summarised in Fig. 2 taken from the paper by Morikawa, Trenner and Taylor, showing the velocities of the several processes at different temperatures. From the curves it will be seen that the order in which the various bonds in simple hydrocarbons are broken is as follows :



GEOLOGY. By G. W. TYRRELL, A.R.C.Sc., D.Sc., F.R.S.E., The University, Glasgow.

PETROLOGY OF IGNEOUS ROCKS—GENERAL AND EUROPEAN.—Recent investigation of the causes of the diversification of igneous rocks (to use a convenient new term introduced by H. L. Alling)—a problem quite distinct from that of the ultimate origin of igneous magmas—has resolved itself into a vigorous controversy between the pure differentiationists, and the advocates of various degrees of assimilation aided by gaseous transfer processes. What may be called the Durham school, led by A. Holmes and D. L. Reynolds, advocate indeed a theory of the metasomatic origin of many igneous rocks through processes involving the mobilisation of country rocks by gaseous emanations from magmas of ultrabasic composition.

In his paper "Recent High-temperature Research on Silicates and its Significance in Igneous Geology," N. L. Bowen (*Amer. Journ. Sci.*, XXXIII, 1937, 1-21) shows that in each of six systems which have been investigated in detail, the residual liquid from fractional crystallisation is enriched in silicates of the alkalis and aluminium, whether the other components of the systems are lime-alumina-silicate, lime-magnesia-silicate or iron silicate, and that the same enrichment will therefore occur in residua from mixtures of silica, alumina, ferrous oxide, magnesia, lime, soda and potash. These oxides make up some 97 per cent. of the composition of the average igneous rock. The equilibrium relations of the system $(\text{NaAlSi}_3\text{O}_8 - \text{KAlSi}_3\text{O}_8 - \text{SiO}_2)$, "petrogeny's residua system," have also been investigated. The liquids of lowest temperatures of crystallisation are represented by a well-defined valley in the fusion surface; and rocks rich in alkali-aluminium silicates, such as the East African rift valley lavas, are found to have compositions lying in this valley. It is concluded that crystal \rightleftharpoons liquid equilibrium has been the

dominant control in the production of rhyolites, trachytes and phonolites, for the most part as residual liquids of crystallising magmas.

Since pure magnesian olivines crystallise at 1890° C., and an admixture of 75 per cent. of the iron olivine (fayalite) would only lower the F.P. to 1500° C., N. L. Bowen and J. F. Schairer (*Rept. of XVIth Internat. Geol. Congress, Washington 1933, 1936, 391-6*) suggest that it is highly improbable that dunite liquids have been injected as such into the accessible parts of the earth's crust. They suggest that dunite dikes and sills were formed from complex magmas which were largely crystallised at the time of intrusion, and that the olivine was left behind when the residual liquid (probably of gabbroid composition) was eventually forced on to some other part of the fissure.

J. Gilluly has discussed "The Water Content of Magma" (*Amer. Journ. Sci.*, XXXIII, 1937, 430-41). Analyses of average igneous rocks indicate that average magma contains not less than 1.5 to 2.0 per cent. of water. But the phenomena of volcanism, migmatisation, granitisation, and such low-grade metamorphic processes as chloritisation, saussuritisation and albitisation, suggest that the primary water content was much greater than can be deduced from "average" analyses. Gilluly suggests that values of 4 per cent. for basaltic magmas and 8 per cent. for granitic magmas in depth, are more in keeping with the geological data; and that these figures are consistent with the hypothesis that the hydrosphere has arisen from the differentiation of the basaltic layer of the earth.

In a valuable paper on "The Crystallisation Process of Basalt," T. F. W. Barth (*Amer. Journ. Sci.*, XXXI, 1936, 323-51) establishes the approximate position of the boundary surface (in the "basaltic" quaternary equilibrium system albite, anorthite, diopside, hypersthene) that separates liquids precipitating feldspars from those that precipitate pyroxenes (\pm olivine). The same basaltic liquid may, under different conditions of cooling, give rise to (1) an over-silicated, (2) an under-silicated, or (3) a neutral residual magma. But Barth nevertheless virtually agrees with the views of W. Q. Kennedy, who postulated two different kinds of initial basaltic magma, when he admits that *normally* (Barth's italics) the requirement for producing an under-silicated residuum is an initial basaltic liquid carrying normative nepheline.

C. N. Fenner's paper, "A View of Magmatic Differentiation" (*Journ. Geol.*, XLV, 1937, 158-68), is a short résumé of some of the major difficulties encountered in the explanation of differentia-

tion by means of a single process. He concentrates attack on the theory of differentiation by crystal fractionation.

A paper by T. Krokström "On the Association of Granite and Dolerite in Igneous Bodies" (*Bull. Geol. Inst. Upsala*, XXVI, 1937, 265-77), is partly intended as an answer to von Eckermann's criticism of Krokström's interpretation of the origin of the Breven granophyre. But it is also a valuable discussion of the general subject. He shows that the hypothesis of crystallisation-differentiation and assimilation are inadmissible for the great dolerite dikes of Central Sweden, and argues that A. Holmes's conception of partial fusion of country rocks is a more likely hypothesis to explain the formation of large bodies of granophyre magma in association with dolerite.

A. Holmes criticises the "Idea of Contrasted Differentiation" (*Geol. Mag.*, LXXIII, 1936, 228-38) recently put forward by S. R. Nockolds (*SCIENCE PROGRESS*, XXVIII, 1934, 692), on the grounds that it conflicts with the experimentally-established principles of crystallisation-differentiation, and that the proportion of acid residuum formed near the end of the differentiation process is so small that its separation from an interlocking crystal-mesh would be mechanically impossible.

The main point in Nockold's reply (*Geol. Mag.*, LXXIII, 1936, 529-35) is indicated by the following quotation: "In the tholeiitic magma type the pyroxene and plagioclase (together with iron ore) crystallise early, reacting with the liquid in the normal way until they have almost exhausted it in these constituents. At this stage a residuum is left of highly contrasted composition. If this cannot react with the early-formed crystals . . . it will solidify as an acid residuum or separate intrusion."

In a continuation of the controversy A. Holmes (*Geol. Mag.*, LXXIV, 1937, 189-91), while admitting the contrast in composition brought about as the result of crystallisation-differentiation in a tholeiitic magma, points out that the real difficulty is the mechanical separation of the contrasted parts so as to form separate magmatic bodies.

Miss D. L. Reynolds further develops her views on the theory of the metasomatic origin of many igneous rocks, originally based on her Newry investigations, by an additional paper on "The Two Monzonitic Series of the Newry Complex" (*Geol. Mag.*, LXXIII, 1936, 337-64). The hybrids of Seeconnell type include two analogous rock-series of monzonitic composition, each converging towards syenite, derived respectively from biotite-pyroxenite and biotite-peridotite magmas. The interpretation adopted is "essen-

tially one of cumulative pyrometasomatism of the invaded sedimentary rocks by the ultrabasic magmas, with accompanying introduction of energy possibly in sufficient quantity to lead locally to the generation of magma."

In her paper, "Demonstrations in Petrogenesis from Kiloran Bay, Colonsay. I. The Transfusion of Quartzite," Miss Reynolds (*Min. Mag.*, XXIV, 1936, 367-407) shows that "micropegmatite, syenite, and appinite have been developed by replacement of quartzite xenoliths engulfed in hornblendite magma. The syntectic rock types occur either separately or in concentric zones in individual xenoliths. . . . The process involved the differential diffusion of the various magmatic constituents into the quartzite; of the major constituents, aluminium, potassium and sodium appear to have been introduced first." The syntectic syenites and appinites thus produced may become mobile enough for "veins" of truly igneous character to be injected into the adjacent rocks. From the evidence presented by this occurrence a number of important petrogenetic considerations arise, which tell against the theory of crystallisation-differentiation, and in favour of the theory of metasomatic origin of many igneous rock types.

A Russian view of the genesis of alkaline igneous rocks, based on many years of work in the Kola Peninsula, is given by B. M. Kupletsky (*Bull. Acad. Sci. U.S.S.R.*, 1936, 329-39, 337-9 [English summary]). He shows that this classic locality has examples of (1) nepheline-syenites in association with alkali-granites; (2) alkali-granites and syenites associated with basic and ultrabasic rocks such as pyroxenite; and (3) ijolitic intrusions with unusual contact effects such as the syenitisation of sandstones, and the development of melilite rocks and carbonatites by the absorption of limestones.

Miss D. L. Reynolds has re-examined the "Contact Phenomena indicating a Tertiary Age for the Gabbros of the Slieve Gullion District" (*Proc. Geol. Assoc.*, XLVIII, 1937, 247-75) in the light of J. E. Richey's recent work which tended to show that the gabbros were of Caledonian age. She comes to the conclusion that the gabbros are definitely younger than the Newry granodiorite and are, in all probability, of Tertiary age. In one locality, however, the Newry granodiorite actually sends veins into the gabbro, but this is ascribed to the phenomenon of *rheomorphism* (Backlund). It is believed that the Newry granodiorite became mobilised at the contact by pyrometasomatism due to the Tertiary gabbro magma, and thus became capable of flow, and of veining the earlier-solidified gabbro.

N. Harris has published an important paper on "A Petrological

Study of the Portrush Sill and its Veins" (*Proc. Roy. Irish Acad.*, XLIII, Sect. B, No. 9, 1937, 95-134). The bulk of the intrusion is a coarse mottled olivine-dolerite belonging to the Hebridean Plateau-Magma Type. It passes marginally into a fine-grained intergranular type. The proportions of iron-ore and olivine increase with depth within the sill. Various types of hornfels and their mineral developments are described. Veins of mobilised hornfels pass downwards into the sill from the roof of hornfelsed Lias shale. Other veins and sheets within the sill comprise metasomatised hornfels and also a variety of synthetic rocks which are believed to be due to the action of the magma and its emanations on included rafts of hornfels. The absence of veins in the roof of Lias, and the capacity of the mobilised hornfels to inject the olivine-dolerite beneath, indicate that the hornfels was under internal compression, presumably due to expansion, while the upper part of the sill was contracting and under internal tension.

In his paper on "Contributions to the Petrology of Barnavave, Carlingford, I.F.S. 2. An Occurrence of Quartz-bearing Syenite and Its Xenoliths" (*Geol. Mag.*, LXXIV, 1937, 125-32), S. R. Nockolds describes another occurrence of alkali-syenite of Tertiary age in the British Isles. It is believed that it formed from a true syenitic magma, probably a partial differentiate from the normal granite of the area. The syenite has been contaminated to some extent by xenoliths of basic igneous rock and limestone. The resulting reaction effects are closely investigated with the aid of chemical analyses.

Pending the completion of work on petrogenesis based on the distribution of Ca^{41} , Ca and K in igneous rocks, A. Holmes puts on record four new analyses of Irish and Scottish Tertiary igneous rocks; namely, olivine-basalt, Staffa; basalt, Giant's Causeway; olivine-dolerite, Portrush sill; and rhyolite, Tardree, co. Antrim (*Proc. Roy. Irish Acad.*, XLIII, Sect. B, No. 8, 1936, 89-94).

J. E. Richey's statistical study of the "Variation in the Amount of Apatite in British Tertiary Igneous Rocks" (*Summ. Prog. Geol. Surv. for 1935, Part II, 1937, 46-52*) has yielded some interesting results. Apatite is especially prevalent in the acid mesostasis of such rocks as tholeiites and quartz-dolerites, and in the late feldspathic veins of crinanites, which represent the final residua of crystallisation in their respective magmas. This suggests a connection between P_2O_5 and the volatile constituents. The acid rocks of the same suites, however, show a marked poverty in P_2O_5 , suggesting that the Tertiary acid magmas are not due to bulk-separation of the residual fractions of the above basic magmas.

S. I. Tomkeieff's study of the "Petrochemistry of the Scottish Carboniferous-Permian Igneous Rocks" (*Bull. Volc. Naples, Sér. II*, tome 1, 1937, 59-87) "leads to their genetic classification into three principal and two co-lateral series. The origin of the series is attributed to the influence of alkali-volatile diffusion-differentiation of the primary magma corresponding to olivine-basalt. The origin of the separate members of the series is attributed to crystallisation-differentiation, and in a lesser degree to diffusion-differentiation."

The "Tholeiite Dykes of the Moorfoot Hills," described by R. J. A. Eckford and F. Walker (*Trans. Edin. Geol. Soc.*, XIII, Pt. III, 1936, 366-70), cut Ordovician rocks, trend N.W.-S.E., and show resemblances to the Tertiary tholeiites of the Acklington type and to the Permo-Carboniferous tholeiite dikes of Perthshire. The balance of probability is in favour of their Tertiary age.

"The Composite Sill of St. Leonard's Craig and Heriot Mount, Edinburgh" has now been described by A. G. MacGregor (*Trans. Geol. Soc. Edin.*, XIII, Pt. III, 1936, 317-31) as consisting of non-porphyrific albitised basalt on the S.E. and N.W. of its outcrop, but having a central layer of highly-porphyrific analcite-rich alkali-basalt in intervening localities. The central layer is intrusive, and has made room for itself by lifting its roof.

The Isle of May, at the entrance to the Firth of Forth, has been described by F. Walker (*Trans. Geol. Soc. Edin.*, XIII, Pt. III, 1936, 175-85) as consisting of a single sill of normal augiteschenite. The sporadic occurrence of a dark mesostasis seems to indicate a late concentration of iron in the magma; but veins of still later date are of highly felsic composition, as might be expected.

The major and central part of the Cairnsmore of Fleet Granite, described by C. I. Gardiner and S. H. Reynolds (*Geol. Mag.*, LXXIV, 1937, 289-300), consists of biotite-muscovite-granite, while biotite-granite occupies most of the marginal tracts. The sediments surrounding the mass have been highly metamorphosed, and are mostly transformed into quartz-biotite hornfels, occasionally with cordierite.

"The Western Part of the Criffel-Dalbeattie Igneous Complex," described by Malcolm Macgregor (*Quart. Journ. Geol. Soc.*, XCIII, 1937, 457-86), consists of four closely-allied plutonic masses with associated minor intrusions. In order of age the plutonic masses are composed of quartz-diorite, followed by granodiorites of regularly increasing acidity. The quartz-diorite is believed to have been formed by permeation of a sodic-feldspathic magma into hornfelses which had already been affected by migrating alkalis and alumina. Numerous new analyses are given.

W. Q. Kennedy and H. H. Read have described a differentiated dike from Newmains, Dumfriesshire, and its contact and contamination phenomena (*Quart. Journ. Geol. Soc.*, XCII, 1936, 116-45). Normal markfieldite is differentiated into basic and pegmatitic varieties by fractional crystallisation and filter-press action. Contamination with a calcareous greywacke has led to *regenerative reaction*, defined as renewed precipitation of an earlier member at a later stage in the crystallisation of the same reaction series. Thus the normal course of mafic crystallisation was from augite to hornblende; on contamination the hornblende was followed by an abundant separation of diopside. Another result of regenerative reaction has been to extend the crystallisation-history to give prehnite instead of anorthite.

B. C. King deals with "The Minor Intrusives of Kirkcudbrightshire" (*Proc. Geol. Assoc.*, XLVIII, 1937, 282-306), which include diorite-porphyrity, albite-porphyrity, albitophyre, acid albite-porphyrity, plagiophyre, xenocrystic porphyry and lamprophyre. The problems of albitisation and of the origin of spilitic rocks receive discussion. Three new analyses are published.

Certain "Xenolithic Minor Intrusions in the Loch Lomond District" have been described by J. G. C. Anderson and G. W. Tyrrell (*Trans. Geol. Soc. Glasgow*, XIX, Pt. III, 1937, 373-84). Three classes of inclusions occur in these porphyry dikes: (1) cognate xenoliths (appinites); (2) accidental xenoliths of the local schists; (3) accidental xenoliths of rocks unknown at the surface in the Loch Lomond district, such as staurolite-garnet-gneiss. On these facts conclusions are drawn regarding the nature of the substructure of the district which are in substantial agreement with those expressed by Sir J. S. Flett.

In his paper, "Intrusions of the Glen Falloch Area," J. G. C. Anderson (*Geol. Mag.*, LXXIV, 1937, 458-68) describes small intrusions of rocks belonging to the kentallenite and appinite suites, with two new analyses. The kentallenite, which has an ultrabasic facies, represents a special facies of fine-grained orthoclase-bearing pyroxene-diorite, and appinite of coarse hornblende-diorite.

Dealing with "The Eastern End of the Inch Igneous Mass, Aberdeenshire," G. Whittle (*Proc. Liverpool Geol. Soc.*, XVII, Pt. 1, 1936, 64-95) describes the country rocks consisting of Highland schists and gneisses, and pre-foliation basic and ultrabasic igneous rocks now represented by tremolite-schist, hornblende-gneiss and amphibolite, which are intruded by the post-foliation Inch Mass, consisting mainly of hypersthene-gabbros with their "end-stage" derivatives. Very high-grade thermal metamorphism has been

produced in the contact rocks, and there is a considerable development of both acid and basic contaminated rocks. The importance of volatile constituents in acid contamination is confirmed by the abundance of apatite in the xenoliths and mixture-rocks.

As a result of his work on lamprophyres in Jersey, H. G. Smith (*Geol. Mag.*, LXXIII, 1936, 87-91; *Quart. Journ. Geol. Soc.*, XCII, 1936, 365-83) comes to the tentative conclusions that while the granites of Armorica are of Carboniferous age, the lamprophyres apparently associated with them may be of Tertiary age, the association being fortuitous and depending on fracture conditions. Their magmas may have been produced by the partial re-fusion of pre-existing rocks.

G. S. Hadfield and H. C. M. Whiteside have described "The Borrowdale Volcanic Series of High Rigg, and the Adjoining Low Rigg Microgranite" (*Proc. Geol. Assoc.*, XLVII, 1936, 42-64), with three new analyses each of the Borrowdale andesites and of the Low Rigg microgranite. Garnets occur in both rock types; in the lavas they are due to solfataric action, but in the microgranite they are probably xenocrystic, perhaps derived from digested lavas.

The discovery of pillow-lavas by W. J. McCallien at Strabane, co. Tyrone, constitutes the first record of this structure in the Dalradian of Ireland (*Proc. Roy. Irish Acad.*, XLIII, Sect. B, No. 2, 1936, 13-22). The rocks are spilites, sometimes porphyritic, which are now transformed into albite-epidote-chlorite-hornblende-schists.

The "Large Pre-Cambrian Intrusive Bodies in the Southern Part of Norway," described by T. F. W. Barth (*Rept. of XVIth Internat. Geol. Congr., Washington 1933*, 1936, 297-309), consist of granites and anorthosites. The granites are believed to have originated by anatexis, sometimes forming migmatites and gneisses, sometimes large bodies of pure granite. The later anorthosite rose from a deep centre in the northwestern part of the area, brecciating, dissolving and assimilating the gneisses, until the granitic residual liquid spread out synclinally over a part of the old gneiss terrane.

A. Kvale's memoir "Et kaledonisk intrusiv- og effusiv-felt på Stord" (*Bergens Mus. Aarb.* 1937, *Naturvid. Raek.* No. 1, 138 pp.) describes a great Caledonian igneous massif lying to the south of Bergen. Gabbros, granites, basic lavas (diabase-porphyrates, etc.), acid lavas (quartz-porphyr and granophyre), volcanic conglomerates and tuffs occur in the complex. The effusive members are older than the intrusive; the gabbros older than the granites. The whole forms a co-magmatic province of Ordovician age.

In his study of the Loos-Hamra region of Sweden (SCIENCE

PROGRESS, XXXI, 1937, 510) H. von Eckermann includes a long section on the Jotnian dolerites (*Geol. För. Förh. Stockholm*, 58, 1936, 129-343) in which he advances a new conception of their occurrence and differentiation. He regards them as having been intruded in three distinct pulses. They have differentiated through monzonitic types to quite acid facies, and show magmatic features which suggest that they and the Rapakiwi granites belong to one and the same magmatic province.

In his memoir on "The Hällefors Dolerite Dike and Some Problems of Basaltic Rocks," T. Krokström (*Bull. Geol. Inst. Upsala*, 26, 1936, 113-263) has made a parallel investigation to that which he made on the Breven dike (SCIENCE PROGRESS, XXVII, 1933, 433) some 30 km. to the S.W. An olivine-dolerite injected in two only slightly separated pulses occupies the western half of the dike and the marginal parts of the eastern half; but the central part of the latter is occupied by a dolerite magma which has differentiated to porphyrite. Krokström regards both the main types as differentiates from a common parent magma by a process of gravitational settling; but the granophyre of Breven and traces of analogous acid rocks in the Hällefors dike are believed to have been generated by re-melting of the country rocks in accordance with A. Holmes's recent theory.

The sub-title of F. Loewinson-Lessing's paper on "A Peculiar Type of Differentiation represented by the Variolites of Yalguba in Karelia" (*C. R. Acad. Sci. U.S.S.R.*, 1935, 21-7) is, "A case of splitting of an effusive basic magma into two immiscible liquids." It is suggested that, after the crystallisation of the pyroxenes, the magma split into two immiscible fractions, producing an emulsion represented by the varioles and groundmass, which are of strongly contrasted composition.

The Khibina and Lovozero Tundras of the Kola Peninsula are the largest and most complex intrusions of alkaline igneous rocks in the world, the Khibina mass occupying 1385 sq. km., and the Lovozero mass 485 sq. km. The main rock of both massifs is nepheline-syenite with numerous variations, associated with ijolite, melteigite, malignite, theralite, shonkinite, apatite-nepheline rocks, and a host of other rare types, which abound in complex zirconotitanosilicates and minerals containing rare earths as well as niobium and tantalum.

The Khibina massif consists of complex annular intrusions in which, while the outer margin is steep, the successive rings have an inclination towards the centre of the mass like enormous cone sheets. The Lovozero Tundra was also produced by successive

injections and represents an example of nearly horizontal stratified intrusions like those of Greenland described by Ussing. As the Lovozero massif cuts hornfels with Devonian plant impressions its age (and in all probability that of the Khibina massif too) is post-Devonian. They were probably injected in connection with Hercynian orogeny. These extraordinary alkaline igneous rocks are described by B. M. Kupletsky ("The Geologic Petrographic Structure of the Khibina Tundra on the Kola Peninsula," *Bull. Acad. Sci. U.S.S.R.*, 1936, 1013-40, English summary 1039-40); and in "Minerals of the Khibina and Lovozero Tundras" (abridged English edition of the Russian monograph under the same title) (*Lomonossov Inst. of the Acad. Sci. U.S.S.R.*, 1937, 152 pp.).

A full description of the geology and petrology of the famous Plauen Syenite mass—often regarded as the typical syenite—is given in a previously overlooked memoir by H. Ebert, "Die Elbtalzone und das Lausitzer Massiv im Bereiche des Kartenblattes Dresden" (*Erläut. z. Geol. Karte von Sachsen* 1:25000, Blatt 66: Dresden. III. Aufl. 1934, pp. 9-50).

In an important comprehensive study of the Eibenstock-Neudek granite mass, which occurs as a plutonic associate of Variscian orogeny in the Saxon Erzgebirge, E. O. Teuscher (*Min. u. Petr. Mitt.* 47, 1936, 211-62; 273-312) describes first the true "magmatites," and then the later "pneumatolytes" and "hydrothermalites" associated with them. Collectively these rocks belong to a unitary magmatic sequence. The second paper deals with the "autometamorphites" due to subsequent reaction processes.

Fourteen occurrences of keratophyres in the Devonian of the Lahn district have been investigated by H. Götz (*Min. u. Petr. Mitt.*, 49, 1937, 168-215). An unexpected feature of these rocks is the general abundance of alkali augites and hornblendes, and the occurrence of pseudomorphs of nepheline in one of them. While the rocks belong to the "Natronreihe" (Niggli), their chemical composition shows a distinct approach to the "Kalireihe." This feature, along with the relative abundance of iron ores both as magmatic constituents and as independent ore deposits, seem to be the specific characters of the keratophyres within the petrographical province.

B. Mauritz has described "Die basaltischen Gesteine der Tatika-gruppe im Plattenseegebiet (Ungarn)" (*Min. u. Petr. Mitt.*, 48, 1937, 373-400). Biotite and minerals of the zeolite group, including analcite, are widely distributed as primary constituents of these rocks. The basalts belong to the alkalic kindred (probably the trachybasaltic kindred, as the norms disclose a few per cent. of

nepheline). Numerous excellent new analyses by Dr. H. F. Harwood are published.

A laccolithic body of Palaeozoic granodiorite on the Malka R., Caucasus, has been petrologically studied by S. P. Soloviev (*Amer. Journ. Sci.*, XXXII, 1936, 380-91) with the aid of three new analyses. The investigation was made in the course of a study of the radium content of the mass. The average content of Ra per gram of rock was 1.89×10^{-12} grams, and the amount of Ra decreases systematically from roof to floor of the laccolith.

C. Burri and I. Parga-Pondal deal with "Neue Beiträge zur Kenntnis des granatführenden Cordieritandesites vom Hoyazo bei Nijar (Prov. Almeria, Spanien)" (*Schweiz. Min. u. Petr. Mitt.*, XVI, 1936, 226-62). It is suggested that the rock has been produced by the addition of 20 parts of garnet-biotite-sillimanite-gneiss plus 5-15 parts of silica, to 75-65 parts of quartz-monzonite magma.

I. Parga-Pondal has dealt at length with the chemistry of the Kainozoic igneous rocks of Spain, with numerous new analyses, in a Spanish publication (*Trab. d. Mus. Nac. d. Ciencias Naturales*, Ser. Geol. No. 39, 1935, Madrid, 174 pp.).

BOTANY. By PROFESSOR E. J. SALISBURY, D.Sc., F.R.S., University College, London.

THE Italian forests present an altitudinal succession of four zones which, in order from below upwards, are the Lauretum, the Castanetum, the Fagetum, and the Picetum. Dr. A. de Philippis (*R. Stazione Sperimentale di Selvicoltura*, pp. 169, Firenze, 1937) has made an extended analysis of the climatic relations of these zones in relation to the data at present available. This analysis shows that the closest approximation between climatic data and vegetation distribution is given by the ratio of annual precipitation to mean annual temperature. Pavari's classification on a thermal basis corresponds satisfactorily with the forest zones when precipitation data are also taken into account. His zones were determined by the mean annual temperatures and that of the extreme months, but precipitation is shown to account for transgressions of the one zone into the others. The author rightly lays stress upon the need for exact investigations into the biology of the species concerned and their responses to climatic conditions.

Dealing with the littoral zonation of Fucaceæ in Holland (*Jour. Ecology*, XXV, 431, 1937), J. S. Zaneveld finds that *Fucus spiralis*, which occupies the highest zone, occurs where there is from 28 per cent. to 75 per cent. of exposure. The next zone dominated by *Ascophyllum nodosum* has an exposure range of from 15 per cent.

to 62 per cent. *Fucus vesiculosus* is dominant where exposure is from 6 per cent. to 49 per cent., whilst *Fucus serratus* occurs from where the shore is uncovered for nearly half the day (44 per cent.) downwards to below the level at which there is no exposure. During exposure the rate of water loss is most rapid from *Fucus serratus* and least so from *Fucus spiralis*, the rate of water loss diminishing, amongst the four species studied, with the degree of exposure which they normally endure. Measurements showed that the higher the level of the species the thicker were the cell walls and the higher was its water-content in relation to the dry weight. But it was also found that the rate of water loss from the cell walls was greater for *Fucus spiralis* than for *Fucus serratus*.

G. Blum records determinations of osmotic pressures of plants from Eastern Java (*Berichte d. Schweiz. Bot. Ges.*, B, 47, 400, 1937). The average for the leaves of herbs of sandy shores was 22.3 atmospheres, for the trees of moist beaches 23.8 atms., for the foliage of trees of firm ground 28.1 atms., and for the foliage of mangrove trees 32.9 atms. An osmotic pressure of 73.9 atms. is recorded for *Acacia leucophylla* growing in a dry region.

W. Vischer, in the same Journal (p. 225), discusses the polymorphism of certain Heterococcales.

The vegetation of the banks of river deposits in various French rivers is described by P. Hagene (*Bull. Soc. Hist. Nat. Toulouse*, LXXI, pp. 52, 1937). Most of the species are either hemicryptophytes or annuals, the former representing from 13 per cent. to 53 per cent. and the latter from 10½ to 88 per cent. The species which occur on most of the examples studied number sixteen, and of these constants the annuals are *Polygonum aviculare*, *P. persicaria*, *P. lapathifolium*, *P. convolvulus*, *Raphanus raphanistrum*, *Chenopodium album* and *Linaria minor*. The perennials are *Agrostis alba*, *Salix purpurea*, *Equisetum arvense*, *Rumex crispus*, *Saponaria officinalis*, *Roripa sylvestris*, *Convolvulus sepium*, *Galium mollugo* and *Artemisia vulgaris*. The author found that the seeds of *Agrostis alba*, *Chenopodium album*, *Roripa sylvestris*, *Convolvulus sepium*, *Linaria minor* and *Artemisia vulgaris* will all germinate satisfactorily under a layer of 5 cms. of water. The perennial species are tolerant of submergence and, owing to their vegetative spread, to mobility of the substratum. The total number of species in all the locations examined was 166, among which may be mentioned *Corrigiola litoralis*, *Lepidium virginianum*, *Ludvigia palustris*, *Cyperus fuscus*, and *Teucrium Botrys*. On the calcareous banks of Le Doubs, which contain 12 per cent. of calcium and have a reaction of pH 7.2, there occur such calcicolous species as *Euphorbia helioscopia* and *Reseda*

lutea, whereas on the shingle of La Bordogne, with no carbonates and a slightly acid reaction (pH 6.4–6.5), there occur such calcifugous species as *Corrigiola litoralis* and *Scleranthus annuus*. The same author (*Bull. Sci. de Bourgogne*, V, 1936) has studied the local occurrence of colonies of silicicole species in the prevailing calcareous area of the Jura. He finds that these are developed where there is either no calcium carbonate in the soil or only a trace, though the pH may be as high as 7.4. Those characterised by the presence of *Calluna* exhibited a reaction that was not less acid than pH 6.3.

A detailed study by H. J. Lutz, J. B. Ely and S. Little of the distribution of the roots of *Pinus strobus* in their relation to the soil profile emphasises the relative importance of the various soil conditions on root development. The soil horizon containing most roots was that consisting of amorphous organic matter (H horizon); here the number per square foot was 407 ± 37 , compared with only 137 in the layer of partially decomposed material just above (F horizon) and 314 in the leached (A horizon), forming the uppermost layer of the mineral soil. The B horizon, though enriched from above, contained fewer roots than the A horizon, the average number being 163 ± 21 in its upper part and 84 ± 17 in its lower. The subsoil (C horizon) had only 25 ± 8 roots per square foot, so that there was a maximum root development in the H horizon, diminishing abruptly upwards and more gradually downwards. Increase of root development was found to be associated with increasing exchange capacity and increase of nitrogen content. Increase of organic matter and of finer-textured soil particles was also accompanied by increased root growth, perhaps owing to the better physical conditions and higher moisture content. The soil reaction showed a slight tendency to become less acid with depth, but appeared to have little influence on root growth, perhaps owing to the slight range in reaction which the soils showed. The total exchange capacities recorded for the various horizons in the profiles examined were: F horizon, 55.5 to 87.6; H horizon 56 to 105; A horizon, 5.6 to 18.6; B1 horizon, 1.3 to 12.9; B2 horizon, 1 to 6.6; C1 horizon, 0.56 to 5.14; and C2 horizon, 0.2 to 7.9 milligram equivalents (*School of Forestry, Yale, Bull. No. 44, 1937*).

PLANT PHYSIOLOGY. By PROFESSOR WALTER STILES, Sc.D., F.R.S.,
The University, Birmingham.

PHOTOSYNTHESIS.—R. Drautz ("Über die Wirkung äusserer und innerer Faktoren bei der Kohlensäureassimilation," *Jahrb. f. wiss. Bot.*, 82, 171–232, 1935) has followed the daily course of photo-

synthesis of plants of a number of different species growing under different external conditions. The principal experiments were carried out on a variety of *Hydrangea*, though some observations were also made on *Solanum tuberosum*, *Euphorbia pulcherrima* and a number of other species. An attempt was made to analyse the results obtained in relation to the environmental factors. In a number of instances a marked depression in the rate of photosynthesis in the middle of the day was observed, a depression which was traceable neither to external factors nor to stomatal movement. A lowering of the intensity of protosynthesis resulted after the latter had been artificially raised by supplying the material with an increased concentration of carbon dioxide or by continuing the illumination of the material during the night, the lowering being more accentuated the higher the intensity of photosynthesis previously reached. The experiments suggest that an internal factor, which changes during the course of photosynthesis, is operative in such instances. Experiments in which different parts of leaves were used showed that, in general, photosynthetic intensity decreases from the base to the apex and from the middle to the margin. The photosynthetic activity of the leaf as a whole depends not only on the species, but also on the age of the leaf. Here also, the differences must be attributed to the operation of an internal factor or factors located in the protoplasm.

The daily course of photosynthesis of plants growing at the high elevation of 3800 metres in the Pamirs has been observed by W. A. Blagowestschenski ("Über den Verlauf der Photosynthese im Hochgebirge des Pamirs," *Planta*, **24**, 276-287, 1935). Here the daily assimilation period is very short, commencing in August at sunrise, reaching a maximum by 10 a.m. or earlier, and falling rapidly to zero round about midday. This course of photosynthesis appears to be largely related to the carbon dioxide concentration which is very low in this region and which follows during the day a similar course to the photosynthetic activity.

The daily course of photosynthesis in the leaves of white mustard has been followed by A. Kjær ("Die Schwankungen der Assimilationsintensität der Blätter von *Sinapis alba* im Laufe des Tages in Abhängigkeit von inneren Faktoren," *Planta*, **26**, 595-607, 1937). The object of this investigation was to determine whether accumulation of assimilates during photosynthesis affects the rate of assimilation. The leaves were exposed to a light intensity of 22,000 lux at 20° C. in normal air saturated with water vapour and the rate of carbon dioxide intake and the content of soluble carbohydrates and starch at different times throughout the day were

determined. As a matter of fact, no definite accumulation of carbohydrates takes place in the leaves, so no depression of assimilation on this account was to be expected, nor was it observed. In two cases a depression in the assimilation rate was observed in the afternoon, and this can be compared with that recorded by Drautz; as it occurred on two dry warm days it may be related to another internal factor, namely, water content.

Another investigation on the same subject has been published by A. J. Heinicke and N. F. Childers ("The daily rate of photosynthesis, during the growing season of 1935, of a young apple tree of bearing age," *Cornell University Agric. Exper. Sta.*, Mem. 201, 52 pp., 1937). These authors measured the rate of absorption of carbon dioxide by a whole apple tree enclosed in a specially designed assimilation chamber. They found considerable variations in the daily amount of photosynthesis, the factor most frequently limiting the rate being light. It should be noted in this connection that a large part of the leaf surface of such a tree is shaded for the greater part of the day so that the incident light possesses only a fraction of the total light intensity. Owing to shading, and perhaps other factors, the older basal leaves perform a relatively small fraction of the total photosynthesis of the tree, the younger leaves accounting for most of the carbon assimilation of the tree throughout the season. The authors consider that the effect of temperature is felt chiefly through respiration and transpiration, the former being influenced by temperature more than photosynthesis, so that with higher temperatures the apparent assimilation tends to fall. The same is the case if transpiration is higher than normal for a given temperature and light intensity. Stomatal movement did not appear to influence photosynthetic activity.

E. K. Gabrielsen and P. Larsen ("Über den Kohlenstoffhaushalt der terrestrischen Halophyten," *K. Danske Vidensk. Selsk., Biol. Medd.*, 9, No. 8, 48 pp., 1935) have investigated the action of the light factor on the carbohydrate economy of two halophytes *Statice limonium* and *Aster tripolium* representing respectively the non-succulent and succulent types of halophyte. Two habitat forms of *Aster* were examined denoted respectively as the *S-Aster*, subjected to daily flooding by the sea and the *s-Aster*, subjected to flooding only once or twice during the winter. The *Statice* and *S-Aster* exhibit a high intensity of respiration, this being about 1 mg. carbon dioxide per hour per 50 sq. cm. of leaf surface as compared with 0.5 mg. in the case of the *s-Aster*. This renders the ratio of maximum apparent assimilation to respiration very small, namely, 1.8 and 4.5 respectively in the former plants whereas in

the *s-Aster* it is about 10.6. Consequently the rate of production of dry matter in these forms is very different. In 24 hours at 20° C. on the clearest and darkest days in July the values for the production in mg. of dry matter by 50 sq. cm. of leaf surface were found to be respectively 13.8 and 9.0 for *Statice*, 30.9 and 15.6 for *S-Aster*, and 49.1 and 30.3 for *s-Aster*.

An examination of gaseous exchange in the submerged water plant *Elodea canadensis* has been made by F. Górski ("Gas interchange in aquatic plants during photosynthesis," *Bull. Acad. Polonaise Sci. et let., Cl. Sci. Mat. et Nat. Ser. B.*, 177-198, 1935). Under the conditions of experiment, which were carried out at a temperature of 20° and with water containing 80 mg. carbon dioxide per litre, it was found that about 70 per cent. of the oxygen diffused into the water while the rest escaped as bubbles. The greater the intensity of photosynthesis the greater the proportion of oxygen released in the form of bubbles. The latter were found to contain 50 to 60 per cent. of nitrogen. The author concludes from these findings that neither the simple bubble-counting method, nor the analysis of the bubbles, affords a suitable basis for absolute determinations of photosynthesis, while for relative measurements he considers the counting of bubbles to be more satisfactory than the analysis of the gas evolved.

K. Arens ("Physiologisch polarisierter Massenaustausch und Photosynthese bei submersen Wasserpflanzen. II. Die $\text{Ca}(\text{HCO}_3)_2$ -Assimilation," *Jahrb. f. wiss. Bot.*, 83, 513-60, 1936) has examined certain aspects of photosynthesis by species of *Potamogeton* in solutions of calcium bicarbonate. It is shown that leaves of these water plants in such solutions when illuminated absorb material through the under surface and excrete substance from the upper surface. All components of the solution are absorbed at the same time by the lower surface, so that H_2CO_3 , HCO' , and CO'' , all serve as sources of carbon. Further, since Ca ions accompany the HCO' , and CO'' , ions into the leaf calcium must either accumulate in the leaf or be excreted. Actually it passes out from the upper surface of the leaf as $\text{Ca}(\text{OH})_2$, and, according to Arens, at the same rate as it is absorbed in association with carbonate and bicarbonate, so that Arens speaks of a $\text{Ca}(\text{HCO}_3)_2$ -assimilation with an assimilatory quotient $\text{Ca}(\text{HCO}_3)_2 : \text{Ca}(\text{OH})_2$ of unity.

With the use of four different light filters E. K. Gabrielsen has compared the photosynthetic activity of leaves of *Sinapis alba* in four regions of the spectrum namely, dark red, red-orange, yellow-green and blue-violet with wave-length ranges in Angstrom units of, respectively, 8600 to 7000, 7500 to 6000, 6400 to 4800 and 5100

to 4000. ("Die Kohlensäureassimilation der Laubblätter in verschiedenen Spektralgebieten," *Planta*, **23**, 474-75, 1935). It was found that photosynthetic activity reached a maximum in the red-orange, was less in the yellow-green and least in the blue-violet.

Determinations were made of the quotient $\frac{A}{E}$, where A is the photosynthetic intensity and E the absorbed energy, and, as was found to be the case in *Chlorella* by Warburg and Negelein, it was also found in *Sinapis* leaves that this quotient increases with decreasing energy absorption. By extrapolating to the limiting value for $E = 0$, the maximum values of the quotient in red-orange, yellow-green and blue-violet lights were found respectively to be 0.26, 0.19 and 0.13. These values, although smaller than those obtained by Warburg and Negelein, are in the same order as those obtained by these workers for *Chlorella*.

R. H. Dastur and R. J. Mehta have made a study of the effect of lights of different wave-lengths on the photosynthesis of leaves of *Helianthus annuus*, *Raphanus sativus* and other plants, as measured by carbohydrate production ("The Study of the Effect of Blue-violet Rays on Photosynthesis," *Ann. of Bot.*, **49**, 809-21, 1935). Red light of wave-length 6200-7000 Å. was obtained from sunlight by a specially prepared carmine solution, and blue-violet light of wave-length 4000-4720 Å. by the use of an ammoniacal copper sulphate solution. The rate of carbohydrate production was examined in sunlight, red light and blue-violet light of the same intensity. It was found that photosynthesis was most active in sunlight and feeblest in blue-violet light. In a typical experiment with *Helianthus* the carbohydrate contents of leaves of potted plants exposed for a six-hour period to sunlight, red and blue lights were respectively 0.282, 0.146, and 0.118, while the carbohydrate content of the leaves of control plants kept in the dark was 0.114, the results in all cases being expressed as grams of carbohydrate per 100 grams of fresh weight of material. The results, as far as they go, are thus in agreement with those of Gabrielsen described above.

Two papers have appeared by R. H. Dastur and L. K. Gunjekar on photosynthesis in polarised light. In the first of these ("Effect of Elliptically-Polarised Light on the Formation of Carbohydrate in Leaves," *Ann. of Bot.*, **48**, 1003-12, 1934) experiments are described which show that the carbohydrate content of leaves of *Raphanus sativus* and *Allium Cepa* exposed to elliptically-polarised light is less than that of leaves exposed for the same length of time to non-polarised light of the same intensity, the source of illumination in each case being a powerful flood-light lamp. In the second

paper ("Energy Absorption by Leaves in Normal and Plane Polarised Light," *Ann. of Bot.*, 49, 273-81, 1935) these workers record the results of an investigation of the absorption of light energy by leaves of 12 different species from non-polarised and plane polarised light beams of equal intensities. With every species the coefficient of absorption was found to be slightly higher in polarised light than in non-polarised light.

ENTOMOLOGY. By H. F. BARNES, M.A., Ph.D., Rothamsted Experimental Station, Harpenden.

GENERAL ENTOMOLOGY.—Few insects have been hitherto described from strata of the Cretaceous period. Recently a comparatively plentiful supply of insects and arachnids has been found in Canadian amber. Although the existence of this deposit of amber at Cedar Lake near the mouth of the Saskatchewan river had been known for nearly half a century, it was not till a few years ago that insect fossils were found in it by Dr. T. L. Walker. Now (*Univ. Toronto Studies, Geol. Ser.*, No. 40, 1937, 62 pp.) twenty-two new species, seven new genera and two new families have been described. The age of this Canadian amber is indicated to be Cretaceous, rather than Oligocene as is the Baltic amber, because of the primitive or generalised characteristics of these insects and of their intermediate position between various existing families. For example, the Collembolan described by F. M. Folsom represents a new family, Protentomobryidæ. Whereas all the twelve species of Collembola from Baltic amber belong to existing genera. In addition to this remarkable Collembolan, an aphid (by E. O. Essig), some Cynipids (by A. C. Kinsey), some Ichneumonidæ, Serphoidea and Chalcidoidea (by C. T. Brues), some Chironomidæ (by M. W. Boesil) and two mites (by H. E. Ewing) have been described in this contribution.

The second part has now appeared (*J. New York Ent. Soc.*, 45, 1937, 149-210) of the review of the available experimental data on insect ontogeny by A. G. Richards. It deals with the larval and pupal stages. Hormones in development, the "differentiation centre" and influence of the nervous system, organ development, regeneration and gradient fields, teratological phenomena and diapause or dormancy all receive attention.

Supra-specific variation in nature is the title of a paper by A. C. Kinsey (*Amer. Nat.*, 71, 1937, 206-22). This is essentially a summary, well worth reading, of the author's publications in 1930 and 1936 on the genus *Cynips* (see SCIENCE PROGRESS, XXXII, 1937, 126). Kinsey uses the term species to define the basic taxo-

onomic unit which is the unit beneath which there are in nature no sub-divisions which maintain themselves for any length of time or over any large area. This unit is variously known among taxonomists as species, subspecies, variety and geographical race. Anything above this Kinsey terms a higher category. It is to be noticed that in these studies the author started with an investigation on the species and is working up towards the higher categories, instead of beginning with the higher categories and passing on later to the species. Unfortunately many taxonomists have done the latter. The conclusion reached is that there is no evolution apart from the modification of existent species or the differentiation of new species. So the same system of genetics which explains Mendelian races and the origin of species will explain the nature and origin of any higher category.

Work on experimental studies of insect populations is becoming more and more popular and it is almost impossible for the general reader to keep abreast of it. For this reason review articles are welcome. T. Park (*Amer. Nat.*, **71**, 1937, 21-33) has dealt with density, what influences it exerts on populations and how it brings about its described effect. Among certain desiderata mentioned at the conclusion of his paper, Park stresses the fact that few precise data exist which merely describe in quantitative terms the growth, maintenance, oscillation and decline of insect populations. Another review paper is by J. Ford (*J. Animal Ecol.*, **6**, 1937, 1-14) on populations of *Tribolium confusum* and their bearing on ecological theory. There is also a summing up by T. Park and Nancy Woollcott of the effects of conditioned flour on certain physiological processes of *T. confusum* (*Physiol. Zool.*, **10**, 1937, 197-211). This information is related to population dynamics.

After discussing the value of sweep net samples by using the standard deviation from theoretical and obtained means, J. R. Carpenter and J. Ford (*J. Soc. Brit. Ent.*, **1**, 1936, 155-61) recommend the method as a simple and fairly efficient as well as rapid means of sampling and comparing areas under reconnaissance. A further discussion on the results obtained by the sweep net method is given by J. R. Carpenter (*J. Animal Ecol.*, **5**, 1936, 231-45). In this paper the literature dealing with quantitative sampling of land animal communities by means of the sweep net is reviewed.

For those who are interested in biological control work the annual reports of the Farnham House Laboratory provide a general idea of work of this nature at present being carried on in the British Empire. The report for 1935-36 has recently appeared (*Seventh Ann. Rept. Exec. Co. Imp. Agric. Bur. 1935-36*, 1937, Appendix XI,

83-93). From this it can be seen that since the formation of this laboratory in 1927-28 the numbers of shipments and specimens of beneficial insects consigned abroad has risen almost steadily each year until 1934-35 when 166 shipments of roughly $5\frac{1}{2}$ million insects were made. The corresponding numbers in 1935-36 fell slightly, but it is claimed that this was on account of an unusual scarcity, due to unfavourable weather, of some of the principal insects. Short accounts are given of specific projects undertaken during the year. These include those on insects affecting cereal and forage crops, deciduous trees, forest and shade trees, garden crops and greenhouse pests. In addition to work undertaken directly on the projects in hand, much research work is done in order to form a good background. An example of this is that of H. S. Hanson (*Bull. Ent. Res.*, 28, 1937, 185-236) on the pine bark beetles. This worker found that their parasites and predators are much more important than is generally appreciated. Further, they are most numerous in young pine stands in the pole stage previous to the first thinning. Acting on this, the investigator devised an experiment in an attempt to keep the state of biological control at its optimum level by the provision of the amount of breeding material necessary to maintain a permanent population of hosts. This in turn would be kept at a level of economic control by the parasites and predators. At the same time the factor of overcrowding, as an automatic control to prevent any undue increase in beetle population, was brought into play in the experiment. It was found that the rate of growth of the crop was the decisive factor. Another example of this type of research work is a paper by K. R. S. Morris, E. Cameron and W. F. Jepson (*Bull. Ent. Res.*, 28, 1937, 341-93) on the parasites of the spruce sawfly in Europe. This investigation started as the result of a severe outbreak of this insect in Eastern Canada. Thirteen species of parasites of the sawfly were then known. In the present paper descriptions of thirty-one species are given, fifteen of which are primary, five primary or secondary and nine secondary only; the status of two is not known. The biologies and immature stages of the obligatory and facultative primary parasites are also described. Nearly twenty-eight million parasitised cocoons and eggs of this sawfly and other closely allied species have so far been despatched from Europe to Canada.

Plant poisons against insects have recently come more and more to the front. In view of this and in order to obtain some idea of the vast amount of progress that has been made in this field, a review of the literature of *Tephrosia* as an insecticide by R. C. Roark (*U.S. Dept. Agric., Bur. Ent. and Plant Quarantine, Washington,*

1937, 165 pp.) is of particular interest. This publication is most comprehensive.

H. W. Frings and Mabel S. Frings (*Science*, **85**, 1937, 428) published a note in which they stated that a formula containing from 20 to 25 per cent. magnesium sulphate (Epsom salts) was as effective as 5 per cent. arsenic in grasshopper bait. Although the authors stated that complete tests had not been made, great publicity was given to this possible control method. Unsatisfactory results were without exception encountered. R. C. Smith (*Science*, **86**, 1937, 226-8) has now given the results of several field trials and has definitely shown that Epsom salts at present cannot be recommended as a satisfactory control for any insect.

It is usual to find dead insects in the open blossom of the Blue water-lily (*Nymphaea capensis*). These insects include such robust forms as *Eristalis tenax*, *E. arbustorum*, *Callicera aenea*, *Syrphus ribesii* and *Rhingia campestris*. The death of these insects has been attributed to mere drowning, to confinement of the insects by occlusion of the flower, to asphyxiation from the heavy odour of the blossom and to the accumulation of carbon dioxide in the floral cup. G. Fox Wilson (*Proc. R. Ent. Soc. Lond.* (A), **12**, 1937, 31-40) has now brought forward evidence to show that death, of the more robust victims at least, appears to be due to a fermenting alcohol liquid in the stigmatic basin of the flower and not entirely to a direct toxic action of the fluid nor to any of the previously suggested causes.

An annotated list of the insects and mites associated with stored grain and cereal products, and of their arthropod parasites and predators, has been prepared by R. T. Cotton and N. E. Good (*Misc. Publ. U.S. Dept. Agric.*, No. 258, 1937, 81 pp.) to supply information regarding the food habits, distribution and relative importance of these insects.

ORTHOPTERA.—A study of the male genitalia of orthopteroid insects forms the subject of a memoir by R. E. Snodgrass (*Smithsonian Misc. Coll.*, **96**, No. 5, 1937, 107 pp.). Besides dealing with the Mantodea, Blattodea, Tettigoniodea and the Acridoidea which belong to the Orthoptera, Snodgrass includes in this work the Isoptera, Embioptera, Zoraptera, Grylloblattoidea and the Phasmatoidea.

LEPIDOPTERA.—It is interesting to hear that different instars of caterpillars are differently affected by insecticides. J. W. Evans (Suppl. *Tasmanian J. Agric.*, **8**, 1937, 18 pp.), working with *Tortrix postvittana*, has shown that white oil and nicotine sulphate combined with a spreader produced complete mortality in larvæ in tunnels

on the under surface of leaves, but the same spray applied to artificially exposed larvæ in their fourth and fifth instars had no toxic effect. Similarly lead arsenate varied in its toxicity with the of the larvæ. In this case the larger larvæ refrained from feeding on treated foliage. Thiodiphenylamine also had no toxic effect on larvæ in their third, fourth and fifth instars which consumed with no apparent ill effects almost equal quantities of treated and untreated leaves.

HEMIPTERA.—Wound healing in *Rhodnius prolixus* has been studied by V. B. Wigglesworth (*J. Expt. Biol.*, **14**, 1937, 364-81). He has found that the histological changes in cells and nuclei activated round a wound are precisely those shown by cells during moulting. Further as in moulting, this process is followed by cell division. The healing reaction can be produced experimentally without interrupting the continuity of the skin. Thus the destruction of the continuity is not responsible for the initial reaction to injury, but restoration of continuity appears necessary to stop new growth.

Nancy H. Wheeler (*Proc. Ent. Soc. Wash.*, **39**, 1937, 141-56) in a paper describing the result of light trap studies on *Emp.* in shows that the use of light traps in connection with a practical research problem may be of considerable value especially when correlated with data obtained in other ways. Incidentally during the period of greatest abundance the males far outnumber the females in light trap collections whereas in field collections the proportion of the sexes is reversed.

Wing development in aphids has been variously attributed to hereditary factors and environmental ones. Among the latter are light and crowding. Physiological changes in the host plant have also been mentioned in the literature on the subject. Using *Toxoptera aurantii* on citrus twigs, E. Rivnay (*Bull. Ent. Res.*, **28**, 1937, 173-9) has conducted some experiments which show that a reduced percentage of water in the food, as well as a low atmospheric humidity, are primary factors in causing wing production. Other factors, such as light, temperature, crowding, humidity, precipitation and growth of the plant influence the water balance in the body of the aphid which in turn causes wing development. In this connection reference should also be made to a paper on the mealy plum has been L. M. Smith (*J. Agric. Res.*, **54**, 1937, 345-64). This in Geological has summarised the literature on wing determination in and to the after experimentation has deduced that starvation of young born at higher temperatures is the explanation of wing formation. Rivnay (*loc. cit.*) however states that temperature does not affect

wing development directly but influences the water balance in their bodies.

J. B. Moore (*J. Econ. Ent.*, **30**, 1937, 305-9) has shown that the aphid *Myzus persicae* is attracted to potato plants when they are sprayed with Bordeaux because of the increased intensity of light reflected from the sprayed surfaces. It appears that the insects follow the inverse-square law of light intensities, thus, it is claimed, showing that light intensity is the primary factor involved. A practical application of this knowledge, i.e. dyeing the dusts used, resulted in a decreased infestation. Black dust was the most effective.

Several interesting points regarding sex ratio have come to light in some work done by H. C. James (*Bull. Ent. Res.*, **28**, 1937, 429-61) on the status of the male in the Pseudococcinae. It is quite clear that the male of *Pseudococcus* is coequal with the female for the propagation of the species. In five species virgin females are incapable of producing offspring and no form of parthenogenesis occurs. The relative abundance of the male sex varies greatly from species to species and the fecundity of the females also varies. Cup-specific variability of the family sex ratios is shown to be the cause of very variable sex ratios at the time of sex determination. It has been found that in the reduction division of the male there are two groups of five chromosomes, in one group they are massed close together and in the other they are loose. The spindle fibres attached to the loose group are always late in appearing and are imperfectly

It is suggested that this imperfection is indicative of an age-related degeneracy which is expressed as a variable vitality that causes variability in their functional efficiency. This explanation would cover the variability both in the specific and family sex ratios. Further, the phenomenon of unisexual families of females only is shown to occur in *P. longispinus*. Delayed fertilisation in *P. citri* resulted in an increased population of males proportional to the period of delay before fertilisation.

AGRICULTURAL PHYSIOLOGY. By ARTHUR WALTON, B.Sc.,
Ph.D., School of Agriculture, Cambridge.

MILK PRODUCTION.—It has long been recognised that those breeds of cattle which have been specially selected for milk production tend to develop a particular bodily conformation recognised as the 'milkmaid' type. It is, however, debatable whether this conformation is caused by specialised nutrition and upbringing and whether the actual milking capacity depends more upon the bodily type or upon the actual size and secretory activity of the udder. Sweet

et alii (*Jour. Agric. Research*, 55, 239, 1937) have attempted an experimental analysis. Beef type and milk type cows of comparable ages were brought up under conditions of dairy management. After a period of trial for milk production they were killed and examined. The internal anatomy and skeletal structures were relatively alike in the two groups, but the amount of secretory tissue and milking capacities were markedly different. The authors conclude that breed differences in production are, therefore, determined more by hereditary factors influencing directly the conformation and inherent capacities of the udder than indirectly through the general bodily conformation.

That the amount and activity of secretion of the udder is not irreversibly determined by intrinsic characters is, however, shown by Azimov and Kronge (*Jour. Dairy Sci.*, 20, 289, 1937), since they find that milk secretion can be increased significantly by injection of a preparation of anterior pituitary gland. The effect is most marked in the first half of the lactation.

MALE FERTILITY.—Much recent experimentation has gone to show that fecundity or the spermatozoon production of the male is an important factor in determining the chances of fertility following mating. Not only must the male produce spermatozoa, but at each mating a sufficient number must be liberated into the female tract to ensure fertility, and this number is very large, perhaps of the order of millions. In addition, the spermatozoa must be active. The influence of external factors, such as nutrition, previous sexual activity and climatic conditions on sperm-production has been studied. One of the most complete analyses of sperm-production is by McKenzie and Berliner (*Agric. Expt. Station, University of Missouri, Bulletin* 265, 1937) on the reproductive capacity of rams. This bulletin will be particularly valuable in determining norms by which fertility and sterility can be gauged. It will also be of considerable value to workers on artificial insemination, the practical application of which is gaining ground rapidly.

ARCHÆOLOGY. By E. N. FALLAIZE, B.A.

EXCAVATION AT BETHLEHEM.—The event of outstanding interest in the archæological world during the last six months has been the exhibition of the results achieved in 1937 by the Geological Section of the Wellcome Archæological Research Expedition to the Near East, which was held at the Wellcome Research Institution, London, N.W.1, from July 12 to August 7. With a number of palæontological specimens from bone beds at Bethlehem were

included "flints," which it was suggested, rather than claimed, showed evidence of having been humanly fashioned.

These exhibits were derived from a pit of gravels and clays at the highest point in Bethlehem. It had been discovered in a search for water, when the attention of the Department of Antiquities was directed to fossil bones which had appeared in the course of the digging. These were examined *in situ* by Miss D. M. A. Bate in 1934, and proved to be parts of the fossilised skeleton of an elephant. This was the first evidence of the former existence of the elephant in Palestine. A concession from the Department was granted to Mr. J. L. Starkey on behalf of the Wellcome Expedition and Sir Henry Wellcome, and the site was excavated by Miss E. W. Gardner and Miss Bate in the seasons 1935, 1936 and 1937. The investigation is not yet complete; and the origin of the deposits and their exact character are still to be determined by further excavation. For the present purpose it is sufficient to say that the gravels, dipping sharply, overlies a cemented scree or breccia. It is evident that the deposits are not now in their original position. Their run may be due to a collapsed floor or the filling of a funnel-shaped hole. The gravels which vary in size from blocks of half a metre to small pebbles, and consist mainly of chert, are water-borne, while the scree shows evidence of sub-aerial erosion. Among the gravels have been discovered the fossilised remains of an extinct fauna, which is not only almost entirely new to Palestine, but is also of an earlier geological age than any hitherto found there. It includes elephant, hippopotamus, antelope, rhinoceros, *testudo* in both a gigantic and a diminutive form, and most important of all, *Hipparion*, the diminutive form of horse, such as is known from various deposits of Tertiary age in Asia and usually held to be characteristic of the Pliocene. This fauna Miss Bate has demonstrated to be of Asiatic origin, and in view of recent reports of *Hipparion* in the Pleistocene of India and East Africa, as certainly not later than Early Pleistocene.

The interest of these investigations for the archæologist lies in the fact that from among the cherts in the gravels, which exhibit the effects of a great variety of forces, Miss G. Caton-Thompson has selected a number, for which she finds it difficult to find any explanation in the action of natural forces. She puts forward tentatively the suggestion that they are humanly fashioned tools, comparing them to the East Anglian pre-Chellean "artefacts" from the Red Crag of Foxhall and the sub-crag detritus beds at Bramford, while some, she maintains, conform closely in shape and edge-trimming to the classic type of Harrisonian eolith. This

is the first time such artefacts have been found in a sealed deposit in Palestine or the Near East. That they are associated with an extinct fauna, which can be assigned to a definite geological horizon is of special significance. The results of the three seasons' excavation are summarised by Miss Gardner and Miss Bate in *Nature*, September 4.

The "implements" from Bethlehem have since been subjected to a critical examination by Dr. Dorothy Garrod and the Abbé Breuil. The former had also had the advantage of visiting the site of discovery. The verdict of both these experts was unfavourable to a human origin. Writing in *Nature* November 6, p. 808, Dr. Garrod points to the absence of a bulb of percussion and the character of the edge-trimming, which is of the vertical type, well known as an effect of flaking by pressure in the soil. She also quotes the opinion of the Abbé Breuil that none of the specimens showed any flaking that could not be explained by the condition of the deposit in which they were found, and comparing them with the flints from Saint-Prest, near Chartres, associated with *elephas meridionalis*, at one time claimed as artefacts, but now generally admitted to be flaked by mechanical action.

MESOLITHIC SITE IN BRITTANY.—Not only has the interest of the megalithic civilisation in Brittany absorbed the attention of archaeologists, largely excluding other periods, but it has also tended to divert critical examination from the statement frequently made that this region was not inhabited before the neolithic period. Some years ago M. and Mme. St. Just Péquart, not content to accept this verdict without exhaustive investigation, began the exploration of the numerous small islands which lie off the coasts, holding it possible that in their isolation evidence of early civilisation might survive, such as on the mainland had long ago been swept away. Their faith was justified by the discovery of a habitation and necropolis site on the small and barren island of Téviec, off the Morbihan, where the absence of pottery and polished stone and the occurrence of a diminutive flint industry of Tardenoisian type indicated that they were dealing with a culture of mesolithic age.

Before summarising briefly the main points in their report on the results of three seasons' excavation from 1928 to 1930, which has been published recently by the Institut de Paléontologie Humaine (*Archives, Mém.* 18, 1937), it will be convenient to refer to another discovery bearing on the presence of early man in Brittany which has been reported recently (*l'Anthropologie*, T. 47, 3-4). M. R. Mazères, when examining the quaternary deposits

of the cliffs of the bay of St. Brieuc (Côtes-du-Nord) found two deposits of loess, a lower and earlier, and an upper and later, separated by the remains of a raised beach of marine origin. The earlier deposit he assigns to the Riss glaciation, the raised beach to the Riss-Würm inter-glacial, and the upper loess, which shows two distinct phases of deposition, to Würm I and Würm II. In the earlier deposits of the upper loess, supporting the attribution to Würm I, he found a dozen flint implements of Mousterian facies, and a number of flakes of diabase and other rock, showing the same technique, and a reindeer tooth, as well as a number of bones of indeterminate character. The unusual employment in the palæolithic period of a material other than flint is attributed to the extreme scarcity of the latter in this neighbourhood. From the later deposits assigned to Würm II came two well-formed carinated flint scrapers of Middle Aurignacian type, another reindeer's tooth, and a tooth of one of the *Bovidae*. This is, as indicated previously, the first recorded instance of the discovery of implements of palæolithic man in Brittany; although it is said that flints were associated with a mammoth's tusk discovered not far from the locality of the present find ten years ago.

To return to M. and Mme. Péquart. The Island of Tévéc is situated at about eighteen hundred metres from the shore of the Bay of Quiberon. It measures only some 400 metres by 200 at its greatest breadth, and is entirely barren and without water. At the time of its occupation in the mesolithic age, it would seem that it was joined to the mainland. The mode of life of the inhabitants was entirely riverine, and not marine. They were neither hunters nor fishers, and lived almost exclusively on shell fish. The habitation site is about 200 metres square. At one time it must have been much larger, but it has been greatly reduced by marine erosion. It is composed of an indurated black soil, which, however, crumbles readily on handling, owing to the organic matter it contains. This consists of kitchen refuse, shells, bones, etc., with which are found personal ornaments, implements, etc., although the flint industry is not rich. The implements include the characteristic diminutive geometric Tardenoisian forms. A number of hearths of various types were found, the most numerous being the domestic, which showed evidence of long usage in their blackened stones. Other forms of hearth appear to have been used for cooking, possibly at funeral feasts, and for ritual purposes. No traces of permanent habitations were found. The most interesting feature of the excavation was, however, the discovery of twenty-three burials, in which the grave furniture included necklaces of shell

and pointed to a ritual use of deerhorn. Enough of the skeletal remains of twenty-one individuals survived to provide material for anatomical investigation. The burials were of male and female adults, adolescents and juveniles. Several graves contained more than one individual, and frequently a child was buried with an adult, not necessarily a female. The skeletal remains were submitted to M. Marcellin Boule and M. H. Vallois for examination; and they have reported on them in detail. No individual had attained an advanced age. Apparently the community was not long lived, at least so far as this evidence indicates. After comparing these remains with all other known examples of mesolithic man, MM. Boule and Vallois are unable to indicate any special affinity, and suggest finally that Tévéc man may be a remote and to no little extent modified descendant of the Chancelade man of Magdalenian times. This agrees with the conclusion of the excavators, who finding no affinities with cultures elsewhere sufficient to warrant an attribution of origin, inclines to the view that the Tévéc civilisation is a local development derived from an unknown palæolithic culture of Brittany. The discovery of palæolithic implements by M. Mazères at St. Brieu, not yet reported at the time the authors wrote, would lend colour to this view.

The Tévéc site is obviously of great interest as giving a very complete view of a mesolithic settlement and its inhabitants. The authors emphasise its importance—to Brittany, as the first evidence of man in Brittany before the neolithic period—as it was at the time they made their investigation; to France, as the first site of the kind to be discovered in the country and as affording a type site for the French mesolithic; and to European archaeology at large as providing a link between the mesolithic civilisation of Northern Europe and that of the South.

PALÆOLITHIC SUCCESSION IN BRITAIN.—A series of studies of the industries of the palæolithic period, which promises to be of no little value for the student of the prehistoric archaeology of Britain, is initiated by Mr. T. T. Paterson in the *Proceedings of the Prehistoric Society*, 1937, 3, 1. He begins with an examination of finds at Barnham St. Gregory, a site from which brick-earth had been dug in a valley running parallel to the Little Ouse near Cambridge. Although implements had been found here previously in the brick-earth, the actual site now described was not found until 1933. The implements occur in gravels and sands with intercalated beds of clay and silt, totalling in all a depth of 64 feet. These deposits underlie brick-earth, in which *coups de poing* have been found 3 feet above the gravel surface. Six dis-

tinot industries are identified, of which five belong to the gravels. These are distinguished on the evidence of geological horizon, state of wear and patination, and typology. The earliest industry is heavily rolled and battered, and deeply patinated. It is found deep down in the gravels, whereas the other industries are confined to the top layer, their relative age being indicated by their depth in the gravel, as well as by patination and wear. The sixth industry comes from the brick-earth and is essentially Acheulean, whereas the earlier gravel implements are essentially flake implements. More than 1500 implements have been taken from the pit. Considering the industries as a whole, Mr. Paterson holds that at Barnham we have a series of industries showing progressive development along indigenous lines, uncontaminated by contact with other cultural techniques. Though it belongs neither to Clactonian nor proto-Levalloissian, its position is such as to warrant the suggestion that it be called the Barnham sequence of the Clactonian.

Mr. Paterson's study of the Barnham pit is of considerable importance in relation to the question of geological sequence; but its discussion must be passed over to refer to an interesting result which emerges from the discovery by Mr. J. Reid Moir and Mr. J. B. Calkin of upwards of forty Clacton flakes and rough-outs at South Acre, Norfolk (*Nature*, October 23, p. 731). From the equation of the South Acre gravel with the uppermost Cannonshot gravel of Norfolk and this in turn with the Chalky Boulder Clay of Suffolk, it is deduced that the implements date from the close of the Hoxne inter-glacial. The implements and the character and level of the South Acre deposit are shown to be precisely similar to those of Slindon in Sussex, where a palæolithic floor was found resting on a raised beach and covered with Coombe Rock. It is thus possible to link up the Slindon Coombe Rock with the South Acre deposit, and the Upper Chalky Boulder Clay. Hence it is evident that the glaciation responsible for laying down these various deposits was of no mean order. The South Acre gravel is more than 20 feet in thickness.

A further contribution to the study of the geological and palæontological succession in East Anglia, of no little importance to archæologists, is a comparison by Dr. Frederick E. Zeuner of conditions in East Anglia and Germany in Pleistocene times. The author writes in support and amplification of the scheme tentatively put forward by Professor P. G. H. Boswell in 1932 and 1936. He shows (*Proc. Prehist. Soc.*, 1937, 3, 1) that there is a remarkable similarity in the East Anglian and the North German series

in (1) stratigraphical sequence, (2) in the palæontological evidence from the Cromer Forest Bed and that of Mosbach and Mauer, and (3) a fair agreement in the archæological sequence. In the geological evidence the correlation Dr. Zeuner has worked out is as follows: (6) Scottish re-advance—Pomeranian—Würm iii; (5) Hunstanton Brown Clay—Wechsel—Würm ii; (4) Upper Chalky Boulder Drift—Warthe—Würm i; (3) Great Chalky Boulder Clay—Saale—Riss ii; (2) Norwich Brick-earth and (?) Cromer Till—Elster—Mindel ii; (1) a possible glaciation in late Crag times—a supposed glaciation of unknown extension—Günz. The evidence from Hoxne is the first from a British station to show a minor glacial oscillation correlated with the pre-Würm or so-called “warm Mousterian” of Germany between Saale and Würm i. This implies the identification of Hoxne as Riss-Würm and not Mindel-Riss as some would maintain. A comparison of the Cromer Forest Bed fauna with the Mosbach and Mauer indicates that it belongs, as they do, to the Günz-Mindel interglacial, while the Crag, affording evidence both geological and palæontological of a cool climate, or even of two cool sub-phases, may be regarded with some reserve as Günz. The archæological succession, taking the Crag industries as Günz and the Chellean as Günz-Mindel interglacial, while Clactonian III (High Lodge) is assigned to Riss-Würm, is shown to coincide sufficiently closely with the archæological sequences and their geological correlations in France and Germany.

NOTES

Ambix¹ (R. B. P.)

The first Number of this Journal, dated May 1937, is introduced by Sir Robert Mond, the President of the Society responsible for its production. Sir Robert states that the task to which its members have set themselves is that of deciphering the past history of science, a task which has proved attractive to many distinguished chemists in the past and is alluring to not a few well-known present-day philosophers who are devoted to research into the inner meaning of the records of early enthusiasts, the origin of theories and the history of discoveries. The results of their endeavours will be embodied in the new publication. The title is the Greek term for an Alembic, the typical apparatus of alchemy.

Curiosity may, for a time, induce a man of science to give a passing thought to such speculations, but this delving into the past requires steady application and more than an ordinary acquaintance with languages, classic and modern, if the researcher digs below the top spit. This is demonstrated in the paper contributed by Professor Partington—"Albertus Magnus on Alchemy"—an example of scholarly industry, with exactly a century of bibliographical references. He reveals Albertus, who was canonised in 1931, as a critic and a commentator of alchemy as well as a practical scientific worker. Albertus experimented and directed experiments on his own initiative—not without regard to the influence of the stars on the operations.

Mr. Julius Ruska discourses on the "Methods of Historical Research" dealing, *inter alia*, with the records collected by Borrichius, Schmieder, Kopp, Berthelot and Von Lippmann on "The Life of Morienus" and the legend of his conversion of Sultan Calid. Mr. Ruska emphasises the need for further translations of, and

¹ *The Journal of the Society for the Study of Alchemy and Early Chemistry*, Vol. I, No. 1. Edited by Dr. F. Sherwood Taylor, 8, Breems Buildings, Chancery Lane, E.C.4. [Pp. 92.] Free to members (annual subscription £1 1s.); non-members, Libraries and Institutions, £1 4s. (post free) for four issues.

commentaries on, early chemical works and for the application of critical methods for the disposal of illusions, in order to arrive at truth. This desideratum and the methods of historical research are clearly illustrated by Dr. Sherwood Taylor in his investigations into the "Origins of Greek Alchemy" as evidenced by Hellenistic Egyptian texts, in which he introduces, incidentally, quotations from an Assyrian tablet attributed to the eighth century and from Chinese alchemical texts. Numerous Greek MSS., most of which have been translated by Berthelot, are to be found in the Libraries of Europe. These are concerned with both the practical and mystical aspects of the Art, the earliest dating from A.D. 70. Papyri of the third century preserved at Leyden and Stockholm indicate that the colouring of a metal, so as to imitate gold or silver, was regarded as analogous to the dyeing of cloth, and that "gold-making," or the augmentation of gold, was effected by debasing genuine gold.

Mr. Gerard Heym supplies an introduction to the "Bibliography of Alchemy" for the benefit of students who have only a superficial acquaintance with the literature of the subject, and promises a further contribution which will include historical works, special monographs, etc. He also deals with "The Aurea Catena Homeri" and Dr. Sherwood Taylor supplies a translation of "The Visions of Zosimos."

Another interesting item is a report of a discussion on chemical and alchemical symbolism (with illustrations) to which Professor Partington contributes his findings on the origin of the use of planetary symbols for the metals; Dr. Sherwood Taylor deals with symbols in Greek alchemical writings; Dr. A. F. Titley, with the macrocosm and microcosm of mediæval alchemy; Mr. Gerard Heym with alchemical picture books, and Dr. D. McKie, with chemical symbols used by Oswald Croll, Robert Hooke and Nicolas Lemery.

The Society has embarked on a voyage of re-discovery and it is not beyond the bounds of probability that, in pursuing these absorbing and seemingly altruistic studies, its members may be successful, in the light of present knowledge, in solving problems which foiled their predecessors and in achieving results, not only of interest, but of material value.

The Journal is very well produced.

Miscellanea.

H.M. the King has approved the award of Royal medals by the Council of the Royal Society to Prof. N. V. Sidgwick, for his work

on valency and molecular structure, and to Prof. A. H. R. Buller for his researches on the biology and sexuality of the Fungi. The President and Council of the Society have made the following awards: Copley medal to Sir Henry Dale in recognition of his contributions to pharmacology, especially to the pharmacology of muscle and neuro-muscular transmission; Davy medal to Prof. Hans Fischer for his work on the chemistry of the porphyrins; Buchanan medal to General F. F. Russell for his work on behalf of the International Health Division of the Rockefeller Foundation; Sylvester medal to Prof. A. E. H. Love, in recognition of his work on classical mathematical physics; Hughes medal to Prof. E. O. Lawrence for his development of the cyclotron and its application to nuclear disintegration. Sir William Bragg has been re-elected president of the Society.

The Nobel prize for Physics for 1937 has been awarded to Dr. C. J. Davisson and Prof. G. P. Thomson for their work on the wave properties of moving electrons. The prize for chemistry has been divided between Prof. W. N. Haworth and Prof. Paul Karrer for their contributions to biochemistry.

Lord Riverdale of Sheffield, K.B.E., has been appointed Chairman of the Advisory Council to the Committee of the Privy Council for Scientific and Industrial Research in succession to the late Lord Rutherford. Dr. G. M. B. Dobson, F.R.S., Lieut.-Col. J. H. M. Greenly and Mr. S. K. Thornley have been appointed to be members of the Advisory Council in succession to Prof. A. Fowler, Sir Clement Hindley and Dr. T. Franklin Sibly, who retired from the Council upon the completion of their terms of office. Sir William H. Bragg has also been appointed a member of the Advisory Council.

At the invitation of the Indian Science Congress Association the British Association will be represented by a large and representative delegation of its members at the Jubilee meeting of the Congress which will take place in Calcutta during the week January 3-9. Sir James Jeans will preside over the meeting in place of the late Lord Rutherford. Lord Rayleigh has been elected president of the British Association for the meeting to be held at Cambridge in August.

Prof. Joji Sakurai, president of the Imperial Academy of Japan,

has been elected to succeed the late Marchese Marconi as vice-president of the International Council of Scientific Unions.

Sir D'Arcy Wentworth Thompson has been elected president of the Royal Society of Edinburgh and Sir Thomas Holland president of the Geographical Association for 1938.

The Croix de Chevalier of the Legion of Honour has been conferred on Mr. G. E. Pearson, governing director of the Wellcome Foundation, by the President of the French Republic.

The Carl Lueg gold medal of the Verein deutscher Eisenhütteleute has been awarded to Prof. Sir Harold Carpenter. He is the first Englishman to receive this distinction.

Dr. R. d' E. Atkinson, associate professor of physics in Rutgers University, New Brunswick, has been appointed chief assistant at the Royal Observatory, Greenwich.

We have noted, with great regret, the announcements of the death of the following well-known men of science during the past quarter: Dr. J. R. Airey, mathematician and, since 1933, joint editor of the *Philosophical Magazine*; Major B. F. S. Baden-Powell, formerly president of the Royal Aeronautical Society; Prof. de Burgh Birch, emeritus professor of physiology in the University of Leeds; Dr. W. N. Bond of the University of Reading, physicist; Sir John Dewrance, past president of the Institution of Mechanical Engineers; Prof. J. E. Duerden, until 1932, professor of zoology in Rhodes University College, Grahamstown; Prof. A. W. Gibb, of Aberdeen, geologist; Mr. W. S. Gosset, head of the scientific staff of Messrs. Arthur Guinness, Dublin; Prof. Albert Heim, For. Mem. R.S., of Zurich, geologist; Mr. Richard Inwards, meteorologist; Prof. V. L. Kellogg, until 1931 secretary of the National Research Council of the U.S.A., zoologist; Prof. F. B. Loomis of Amherst College, Mass., palæontologist; Prof. M. Maclean, emeritus professor of electrical engineering in the Royal Technical College, Glasgow; Mr. Andrew Mellon, founder of the Mellon Institute for Industrial Research; Dr. Percy Phillips, director of the Hydrological Service of the Physical Dept., Ministry of Public Health, Cairo; Mr. F. A. Potts of Cambridge, zoologist; Prof. Hans Reck of Berlin, geologist; Lord Rothschild, F.R.S., zoologist; Mr. A. Sharples, head of the Division of Plant Pathology, Rubber Research Institute, Malaya; Mr. F. C. Thompson, lecturer in the Leather Industries Dept. in the University of Leeds; Prof. J. G. Thomson, director of the Dept. of Medical Protozoology at the London School of Hygiene and Tropical Medicine.

In a letter to *Nature* (August 14, 1937) Prof. C. S. Gibson of Guy's Hospital Medical School, states that thin films of gold may be deposited on glass and other surfaces by the decomposition of certain organo-gold compounds (such as diethylmonobromogold) when dissolved in a suitable solvent such as ethanol to which alkali has been added. Objects coated in this way have been loaned to the Imperial Institute by Prof. Gibson and may be seen in the South African Court.

Imperial Chemical Industries Ltd., has developed a new substance for waterproofing textile fabrics which has been put on the market under the name Velan. It is stated that textiles woven with fibres impregnated with it retain their waterproof properties after repeated washing and dry cleaning. It increases the suppleness of the cloth, does not affect its air permeability, and adds little to the cost of manufacture.

The *Bell Laboratories Record* for September 1937 contains an account of the lead-calcium grid storage batteries which are being developed in the Laboratories. Pure lead, otherwise quite satisfactory, lacks the mechanical strength necessary for accumulator grids, and it is customary to obtain the necessary strength by alloying the lead with 9 per cent. of antimony. Antimony, however, is electropositive to lead, so that the local action due to the minute antimony/sulphuric acid/lead cells results in the formation of lead sulphate and a self-discharge of the cells which, in practice, causes a loss of some 25 per cent. of the total charge per month on open circuit. It has been found that lead alloyed with about 0.1 per cent. calcium is hard enough to be used in the grids and since calcium is electronegative to lead, the local action results in the discharge of hydrogen on the lead and not in the formation of lead sulphate. The calcium is dissolved, but inasmuch as it is present as a large number of small particles of Pb_3Ca separated from each other in the lead only the surface particles are dissolved and the acid does not reach the bulk of the calcium underneath. Experiment has shown that, "after a hundred charge-discharge cycles the lead-calcium cells showed a rate of self-discharge of only about one-fifth that of the lead-antimony cells." Laboratory tests of the lead-calcium cells have been satisfactory but production methods have to be developed and service tests carried out before they become available for general use.

The October number of the *Record* contains an account of the new diphonic loud speaker recently introduced to the motion

picture industry under the name Mirrophonic Sound. Two speakers are used, one about 7 feet high for frequencies below 300 and the other, with a horn divided into fifteen exponential cells each 8 inches square at the flared opening, for frequencies above 300. It is specially designed to give accurate reproduction over a field of wide angle. A horn with a single air passage tends to concentrate sound of higher frequencies on its axis.

The Metallurgy Research Board of the Department of Scientific and Industrial Research has published a monograph entitled *Magnesium and its Alloys* (H. M. Stationery Office, 2s. 6d. net) which contains a summary of the papers on this subject published in various parts of the world in recent years. One of the great obstacles to the use of the metal and its alloys at the present time is the readiness with which they corrode in certain types of water and other liquids. They are highly resistant to alkalis, but sea-water spray in the atmosphere greatly increases the corrosion. The addition of from 0.5 to 2.5 per cent. of manganese improves matters but it appears that when the corrosive conditions are severe protection by paint is necessary and then the problem is to produce a film on the metal to which the paint will adhere. "Leaded" petrols produce corrosion of any magnesium surfaces to which they have access in internal combustion engines, but the action can be inhibited by the addition of 1 per cent. of quinoline to the fuel. A number of possible uses of magnesium alloys involve the exposure of the metal to elevated temperatures, and for this reason their mechanical properties when hot become important. Silver increases the ultimate strength of magnesium up to 290° C., but its effect when used alone is not so marked as that of aluminium. Recently cerium has been added to magnesium and cerium-calcium-magnesium alloys have been studied. The monograph states that cerium has a pronounced effect in increasing the strength of magnesium at elevated temperatures. Even small quantities of the order of 1.0 per cent. have a remarkable effect in increasing the hardness of magnesium at 300° C. The addition of a small amount of calcium to the cerium-magnesium alloys is beneficial in preventing oxidation during melting and heat treatment, and also in improving the age-hardening properties. The increased hardness due to heat treatment is, however, relatively small even when calcium is present. A harder alloy can be produced by adding nickel to the cerium-magnesium alloys, but the nickel alloys were found to be very liable to corrosion. This can be slightly reduced by replacing nickel with cobalt and manganese.

The *Bulletin of the Imperial Institute* for July–September, 1937 (Vol. XXXV., No. 3) contains an account of the Sierra Leone diamond field written by its discoverer, Mr. J. D. Pollett, A.R.S.M., of the Geological and Mines Department, Sierra Leone. The first diamond was found by Mr. Pollett in January 1930, when working with the Director, Major Junner, in the Kono district. The crystal was identified as a diamond by Mr. Pollett and Major Junner in the evening of the day of its discovery and next day Major Junner found another. The discoveries were announced by a notice outside the Mines Office at Freetown, but one or two gold prospectors in Sierra Leone at the time failed to find any diamonds and nothing was done until, in March 1931, Major Junner persuaded the Consolidated African Selection Trust Ltd. to send a prospecting party to examine the area. Meanwhile Mr. Pollett found two more diamonds. The prospecting party found others and ultimately, in 1935, the Selection Trust was given the sole right to prospect for diamonds in Sierra Leone through its subsidiary the Sierra Leone Selection Trust Ltd. (except in two iron ore concessions where all mineral rights had already been granted to the Sierra Leone Development Co.). The Government takes $27\frac{1}{2}$ per cent. of the profits and the company pays £7,000 per annum by way of mineral rents.

The diamonds are found in the river gravels in deposits, separated by barren areas, and while it is possible that they have been spread over the whole area from a common source by an ancient and now non-existent river it seems more probable that they have been derived from local basic igneous intrusions. The quality varies from diamonds of the poorest type known as bort, to first-quality gemstones. The heaviest stone found up to the time of the report weighed 144 carats, but this was only of medium quality; the best weighed 78 carats and was sold for £5,000. The total sales value of the production increased from £20 in 1932, and £4,485 in 1933, to just over £500,000 in 1936, and Mr. Pollett considers it certain that the field is assured of a long life.

The same issue of the *Bulletin* contains a reprint of the report on pyrethrum cultivation in Japan prepared by the British Vice-Consul at Seoul. This report first appeared in 1930. It contains a full account of the production and use of the plant with statistics brought up-to-date from reports from the Department of Overseas Trade.

We have received a copy of the *Select List of Standard Scientific and Technical Books* by British authors, compiled by the Association of Special Libraries and Information Bureaux "as a guide in selecting

books for a library." The list is prefaced by a Foreword written by the President of the Royal Society, and an introduction by Sir Richard Gregory, who states that the Book-List Committee "has made every effort to ensure that the books will be regarded as justly representative of existing works in science and technology now available from British publishers" and that "The list should serve a valuable purpose in making such works known abroad as well as afford guidance to standard volumes worthy of inclusion in private or public libraries at home." There are 321 titles altogether arranged under 21 subject heads covering the whole field of pure and applied science except Agriculture and Medicine. The variation in the standard of the selected works, which is intentionally very wide, will be realised when it is mentioned that No. 15 is Whitehead and Russell's *Principia Mathematica* and No. 50 Sir William Bragg's delightful *Universe of Light*. It seems probable that the value of the list would have been increased if some simple means had been adopted to indicate the classes of readers for which each book is suited.

ESSAY REVIEWS

PASCAL, THE SCIENTIST AND THE MAN. By L. N. G. FILON, C.B.E., M.A., D.Sc., F.R.S., Professor of Applied Mathematics in the University of London, University College. Being a Review of **Pascal : The Life of Genius**, by MORRIS BISHOP. [Pp. xiv + 398, with 6 plates and 5 figures.] (London : G. Bell & Sons, Ltd., 1937. 12s. 6d. net.)

To the average educated Frenchman, Pascal is primarily a "*moraliste*," the author of the "*Pensées*," one of the literary and philosophical glories of the "*Grand Siècle*"; to the average educated Englishman (if his education has included Mathematics!) he is a name attached to a theorem. On this side of the Channel, only the specially cultured know the writer and the polemist; and both in France and in England, only the historian of Science remembers the experimenter who abolished Nature's horror of the void.

Mr. Morris Bishop, who gives us the latest life of Pascal, is neither a Frenchman nor an Englishman. He brings to a very old, very difficult and very controversial subject that freshness of outlook which one so readily expects (but does not always obtain) from the New World. A Professor of Romance languages in Cornell University, he is evidently very much at home in that world, so passionately alive, of the French seventeenth-century. And he has given us, possibly for the first time, a Pascal who is, if not true, at least nearly credible.

Pascal has always been an enigma. His mathematical precocity, his excursion into the domain of experiment, his short-lived appearance in the guise of a man of the world, followed by his semi-mystical conversion and his transformation into the unofficial apostle of Jansenism—that curious Calvinistic creed which flamed for a brief space in the midst of the Catholic world—an apostle whose writings have influenced the literature and the thought of France to this day, all the above combine to make a many-sided and puzzling personality, the contradictions of which have not been fully reconciled.

Moreover, certain facts have never been cleared up. There seems little doubt that what remained of Pascal's papers (he tells us himself that he destroyed many of his scientific manuscripts

after the religious crisis of November 1654, and he probably destroyed much besides) was very carefully edited after his death by his kinsfolk the Périers and by the two leaders of the Jansenists of Port-Royal, Arnauld and Nicole. A Pascal legend was created and sedulously fostered.

Only extracts have been preserved of his letters to his friend's sister, Mlle. de Roannez, over whom he seems to have acquired an influence which impelled her to enter the novitiate at the convent of Port-Royal, from which she emerged after his death to make a most unsuitable marriage. None of her letters to him has survived. Their relations remain a mystery, in which Mr. Bishop thinks he has found the key to much that is otherwise obscure in Pascal's character.

Even the authorship of that curious pamphlet *Discours sur les Passions de l'Amour*, discovered in 1842, by Victor Cousin in the Abbey of Saint-Germain-des-Prés (where the other MSS. of Pascal had been originally deposited) and attributed to Pascal, is still in dispute. Many authorities deny that it is the work of Pascal, though Mr. Bishop gives strong reasons for accepting it as such.

By nature and early training Pascal must undoubtedly be classed as a mathematician. The story told by his sister Gilberte of how, at the age of twelve, he discovered for himself a number of theorems in geometry by studying diagrams made with charcoal on the floor of his playroom, has become a commonplace. But in the seventeenth-century, Natural Philosophy knew not the fine distinctions which have since divided Science into almost watertight compartments, and a man might be a mathematician one day and a physicist the next, which indeed happened to Pascal.

His belief in experiment as the basis of all scientific knowledge was doubtless imbibed from the atmosphere of the *Académie libre* to which, at the age of thirteen, he was introduced by his father, Étienne Pascal. This "free Academy" was an informal gathering of those in Paris interested in Natural Philosophy and met in the rooms of Father Mersenne; the members, who were generally opponents of Aristotelianism, included among others Roberval and Desargues. This body may have been the nucleus of the future *Académie des Sciences*, just as the very similar informal meetings of the "Invisible College" at Oxford gave birth to the Royal Society.

Mr. Bishop is evidently impressed by a little essay in which Pascal compares the deductive mind (*esprit géométrique*) with intuition (*esprit de finesse*), and he has built upon it a theory of Pascal's scientific method, which he contrasts with that of Descartes. It seems, however, very doubtful whether Pascal ever really envis-

aged intuition as an instrument of *scientific* discovery. His *esprit de finesse* is the instinct of the man of the world which cuts the Gordian knot of problems too complex for systematic analysis, not unlike what, in a more specialised field, has been termed the "engineering instinct." Still less is there reason to believe that he differed from Descartes in preferring to proceed from particulars to the general instead of from the general to the particular. The sentence in the "Préface sur le Traité du Vide," to which Mr. Bishop appears to refer when he ascribes to Pascal the statement that no amount of *a posteriori* verification can prove a hypothesis, is merely the usual logician's warning against basing a universal assertion on an incomplete enumeration—what we should nowadays call generalisation from imperfect induction. But as all inductions from experiment are necessarily imperfect, this goes directly against the biographer's theory.

Nor could this theory survive a careful reading of another essay of Pascal's entitled "De l'Art de persuader," in which he strongly condemns the evidence of the "heart" (intuition) in purely mundane matters, and admits, as the most infallible method of argument, demonstration from some accepted first principles, which is in fact the method of Descartes. Pascal's antagonism to Descartes (apart from the personal element) seems to be mainly on religious rather than on scientific grounds.

Anyhow, "intuition" sometimes failed to rescue Pascal the scientist from strange lapses, as when he stated, in support of the contention that living bodies were unaffected by all-round pressure, that if a fly were placed in a test-tube partially filled with water and the water then compressed by a piston, the fly would "walk about with liberty and vivacity along the glass," which experiment Robert Boyle having performed with "a strong Flie, it was presently drowned." Mr. Bishop points out that this came from a MS. published after Pascal's death and may have referred to an experiment projected but not actually performed. Even so, it betrays a singularly "Cartesian" inversion of the mental procedure which we are told is characteristic of Pascal.

At the age of sixteen Pascal produced what is probably his greatest contribution to mathematics, his famous mystic hexagram, the theorem now always associated with his name, that the three intersections of opposite sides of a hexagon inscribed in a conic lie on a straight line. This, together with a few other results on conics, was published as a single closely-printed sheet.

Pascal had meant to follow it up by a treatise on Conics. That he did write this we know, because after his death the manuscript

was seen by Leibniz in 1672 and from Leibniz's notes we can form some idea of its contents. These seem to have amounted to a fairly complete treatment of conics on modern projective lines. Pascal proposed to draw over 400 corollaries from his mystic hexagram. He may indeed have done so, for the hexagram is really nothing less than a new definition of the conic and so must contain all the properties of the curve.

The author of this biography of Pascal apparently lays no claim to any specialist knowledge of either Mathematics or Physics. If so he is to be congratulated on the remarkably clear and generally sound exposition which he has given of Pascal's work in these two spheres. But one may reasonably challenge the justice of his verdict that Pascal's achievements do not place him in the first rank either of physicists or of mathematicians. In the case of one who died comparatively young and whose periods of scientific activity were so abnormally short, quality must count at least as much as quantity. The experiment of the vacuum within a vacuum, when he placed a barometer inside an exhausted tube and showed that the gradual readmission of the air caused the mercury to rise slowly above the equilibrium level, was (if really due to Pascal and not, as some think, to Auzoult) a triumph of experimental skill in the conditions of that time, and as decisive a demonstration as the much better known comparison between the barometer heights at the top and foot of the Puy-de-Dôme.

Moreover, the proportion of Pascal's scientific works which have been lost is probably unusually large. Reference has already been made to the destruction of his manuscripts in 1654. Only two have survived of a long list he sent in that year to the *Académie Parisienne*. Much was lost after his death. Thus the treatise on Conics, seen by Leibniz and returned by him to Étienne Périer, has disappeared.

His work on Conics and on Probability alone would entitle Pascal to a very high place among mathematicians. The theory connected with the arithmetical triangle all but anticipated Newton's binomial theorem, and Leibniz admits that it was Pascal's work on the cycloid which inspired his own development of the infinitesimal Calculus.

Mr. Bishop says that the total of days when mathematics was Pascal's chief mental concern "would probably not surpass three years. This is hardly time enough," he adds, "to make a great mathematician."

Would it not be truer to say that only a great mathematician could have produced so much in so short a time? What of Evariste

Galois, whose writing was the work of one night? And surely great mathematicians are born, not made.

Pascal the man is a different story. In some ways he had the mentality, not of a French *bourgeois*, but of a Scotch covenanter. His egocentric intolerance is visible long before he sought the cells of Port-Royal, in the persecution, during his Rouen days, of the unfortunate Brother Forton de Saint-Ange, in his tyrannical and proselytic interference with the lives of his good-natured brother-in-law Florin Périer, of the rest of his family, of his friends, including the Duc de Roannez and his ill-fated sister. And the combined *odium theologicum et scientificum*, which seems to have been one of his dominant characteristics,—one indeed unpleasantly common in that uneasy century—reappears in his castigation of Père Noël, in his enmity to Descartes (not himself, unfortunately, free from reproach), in the vindictiveness of the *Provinciales*, in the callous and not altogether fair treatment which he accorded to the “competitors” in the affair of the cycloid. “Consider, I beg of you, gentlemen,” said Cromwell, “that you *may* be wrong!” It never seems to have occurred to Pascal that he might be wrong. His conversion was really an expression of his innermost nature; the notion of predestined grace, with its sense of inborn superiority—that spiritual priggishness which takes many forms, religious, artistic and political, from the assurance of being saved to the consciousness of some hypothetical racial superiority—this belief fitted Pascal like a glove, nor was there any need of a supernatural illumination to lead him to Port-Royal. He talks of God, and of Christ, incessantly, but one can read the “*Pensées*” from end to end without a glimmer of a suspicion that the most important Christian command is “Love one another.”

That he was a genius no one will deny, save those who adopt Carlyle's definition of “an infinite capacity for taking pains”—the “*longue patience*,” which certainly was not Pascal's. But the lightning intuition, the revealing flash, which most of us associate with genius, were his without question, and this genius permeated all that he did, in every domain.

Perhaps the real key to his character is that he was a sick man, struggling with disease from childhood upwards, his will-power stretched to breaking-point in an effort to pierce the veil of physical suffering. That such an effort must have hardened his personality and exaggerated it to distortion seems a possible conclusion. His latest biographer does indeed give us a vivid and convincing picture of a tormented mind, which found a strange relief from physical pain in the exaltation of self-inflicted moral agony. When we

read of his last months, darkened by illness, bereavement, defeat and the bitterness of work undone, the little traits are forgotten and we think only of that great and tragic figure whose epitaph might well have been that of King Lear

Vex not his ghost : O let him pass ! He hates him
That would upon the rack of this tough world
Stretch him out longer.

THE GREAT ICE AGE. By P. G. H. BOSWELL, D.Sc., F.R.S., Professor of Geology in the University of London, Imperial College of Science and Technology. Being a Review of the second edition of **The Quaternary Ice Age**, by W. B. WRIGHT. [Pp. xxvi + 478, with 23 plates and 155 figures.] (London : Macmillan & Co., Ltd., 1937. 25s. net.)

THE first edition of *The Quaternary Ice Age* was published in 1914, "just before" (as the Author says in his Preface to this second edition) "the outbreak of the European War. That this circumstance did not prevent it being read is apparent from the fact that there is one copy of it at the bottom of the Levant, and, I believe, a second in the English Channel." But what the author does not relate is, that in the difficult times that followed publication he was marooned for a week or two, while engaged on official duties for the Geological Survey, in a village in the west of Ireland, with no other reading matter but this volume which he had long laboured to write, re-write and read in successive stages in proof. Almost *trop de richesse* ? Such a circumstance, which must have produced a feeling akin to nausea in even an enthusiastic exponent, might well explain the long delay in the issue of a second edition of the work, notwithstanding the fact that the first edition had immediately taken a foremost place as a standard text-book. More likely, though, the delay was due to the important advances made in detailed knowledge during the past quarter of a century. What we then learned concerning the events of the Great Ice Age has led to the abandonment of the monoglacial theory in Britain and to a renewal of belief in the older view of alternating glacial and interglacial episodes. Indeed, it may fairly be said that when the first edition of this book was written, the Ice Age had no real stratigraphy, although subdivisions had been established in Britain, America and the Alps.

In the course of the last two or three decades, investigations in many parts of the world have produced an enormous amount of literature, and all students will be grateful to the author for undertaking the onerous task of preparing a summary, and for presenting it in such a readable and attractive manner. But this task has necessitated much more than mere revision of the first

edition ; most of the chapters have been expanded, and many are new. Thus there has been a material increase in length of the book and there are many new illustrations ; although the format is excellent, the book itself is rather heavy.

The chapter-headings alone are a sufficient guide to the wide scope of the work. The physical or dynamical side is dealt with in chapters on Glaciers and Ice-Sheets, Glacial Drifts, Phenomena of Retreat, Theories of the Ice Age, Oscillations of Level in Fennoscandia, Britain and North America, and the author's Isokinetic Theory, to which further reference is made below. The stratigraphical aspects are considered in chapters on the Pliocene Deposits of Britain (which herald the oncoming of the Ice Age), the Older Drift of the British Isles, the Newer Drift, and the River-Gravels of the South of England ; and all threads are drawn together in the regional discussions in chapters on the Glaciation of Britain, of Europe, of the Alps and of North America (with a chapter devoted specially to the Quaternary Lakes of that continent). Contemporary life in relation to the climatic changes has called for chapters on the loess (the dust-like deposit distributed by centrifugal winds, probably during ice-advances) on Quaternary Mammals and on Quaternary Man. And lastly, though perhaps outside the strict limit of the Ice Age, the post-glacial changes of climate in North-West Europe form the subject of a useful chapter.

In the first edition of this book the author pointed out that a modification of the Isostatic Theory was necessary to explain the various levels of the terraces and beaches that mark late-glacial and post-glacial shorelines. Warped shorelines are associated with all glacial centres ; and they rise, on the whole, towards the centres of dispersal of the ice. The author regards these features as the marks of a struggle between rising land (relieved of load by melting of the ice-sheets, *i.e.*, isostatic effect) and rising sea (augmented by melt-waters, *i.e.* eustatic effect). Where these two factors were equal for any prolonged time, well-marked shorelines were formed. The author proposes to call this modification of the earlier conception the Isokinetic Theory.

One aspect of the physical characters of glaciers and of the deposits that result from their melting has received but scant attention ; it is concerned with the interesting structures (as distinct from textures) seen within ice-sheets. These are known as englacial structures and are commonly determined by dirt-bands ; to them seem to be related the very interesting disturbances seen in unconsolidated deposits in various parts of the world, concerning which there is now a considerable literature. Unfortunately,

none of the classic occurrences of these structures, such as Rügen, Møen, Lönstrup, and others appears in the Index, nor does the Index include any reference to the still fascinating and much-visited sections showing these contortions in the Cromer and Ipswich districts, described by G. Slater and others. The neglect of this aspect of the study of ice may explain also the fact that the author's treatment of moraines and drumlins gives the impression of not being altogether up-to-date.

It is high time that the map on page 61 showing the glaciation of the British Isles ceased to be reproduced. It is misleading in its implication that the ice-flows as indicated were contemporaneous ; for any attempt to compress into an instant of time the varying physical events of half a million years is of less than doubtful value.

While we must pay tribute to the wide reading and deep knowledge shown by the author when he is dealing with the physical, physiographical and regional aspects of his subject, we feel that this high standard is hardly maintained in the chapters on the stratigraphy of the Glacial Period. As the author says, the rapid evolution of Early Man (rapid, that is, as compared with contemporary mammals) makes his skeletal remains and implements of great zonal value for the purpose of subdividing and correlating Pleistocene deposits. Admittedly, it is asking a great deal that the expert geologist should be competent and up-to-date in certain branches of archaeology ; but the difficulty has to be faced that the two fields of study now overlap so definitely that a successful exponent of the history of the Ice Age must be well informed in both sciences. Unluckily for geologists, perhaps, detailed information relating to the geology as well as the archaeology of the Ice Age appears in archaeological and not geological publications in Western Europe. This volume on the Quaternary Ice Age will certainly be consulted, if not bought, by archaeologists desirous of learning the latest views regarding the relation of glacial and interglacial phases to cultures and industries of early man. Chapters V, VI, IX, and XVI, which are most concerned in this connection, will prove disappointing to archaeologists. The investigators who interpreted the succession in the east of England may not necessarily be right, but their views, if expounded, should be correctly stated. This succession is important because it is the most complete in Britain, but one gets the impression that the author has not paid adequate attention to it.

We note, for example, that it is hardly true to say that the section at Foxhall Road, Ipswich, yielded to Boswell and Moir a more complete archaeological record than Hoxne (as stated on p. 78) ;

Sainty did not obtain a primitive Chellian implement from the Norwich Brickearth (p. 79); it is not now correct to state that the Chalky-Kimmeridgian Boulder Clay has been proved at Hoxne and Ipswich to be clearly prior to Early Acheulian. Other statements on page 79 are debatable, to say the least, in the light of recent work. It was the conclusion of Boswell, not Solomon (p. 81), that the North Sea Drift was the product of floating ice. As Solomon wrote a paper dealing exclusively with the Morston beach section, we can only conclude that the author has no knowledge of it, for he says (p. 93) that Solomon "hardly makes more than passing reference to this very important point"; the paper in question is not mentioned in the bibliography on the chapter. On page 127 the terms Kimmeridgian and Jurassic have become transposed. The table of classification of human industries on page 269 and the notes on page 274 are too much out-of-date in outlook and generalisation to be of use now in Pleistocene stratigraphy.

Perhaps the most unfortunate omission is that of adequate reference to the succession in the Lower Thames Valley or to the investigator who has, without exaggeration, revolutionised our ideas of the later stages of the Ice Age in relation to Early Man. On page 121, for example, the author speaks of *the* Coombe Rock as Mousterian. There are now known to be several coombe-rocks of different stratigraphical ages; and the term Mousterian in this connection, as elsewhere in Britain, may mean one of many things; in fact, it is inappropriate.

Considerations of space may of course have prevented a fuller and therefore more exact treatment of these questions, but if this was pressing, then it might be urged that the chapters on the theories as to the Cause of the Ice Age could be shortened considerably. When one views the vast field covered by this book, the question certainly arises as to whether it is not expecting too much for one author to deal fully with the complex story of the Ice Age. Has not the time come for joint work by two or more authors—a kind of Priest and King combination?

In justice to the author and to his important work, it should be emphasised that these critical remarks refer in the main to only four chapters of the book. Attention has been drawn to certain defects in order that archæologists, teachers and others who may use the volume for instructional purposes should know in what directions it ought to be supplemented. Critical notes, if given precision, are bound to bulk largely in a review such as this, while praise being more general, is less conspicuous; but the greater part of the work merits the highest appreciation.

REVIEWS

MATHEMATICS

Interpolation and Allied Tables. Reprinted from the Nautical Almanac for 1937. [Pp. 48.] (London: H.M. Stationery Office, 1936. 1s. net.)

THESE tables, which have developed out of the practice of H.M. Nautical Almanac Office, are now issued separately as an aid to computers in a wider field. They are designed to simplify the labour of interpolating into tables where the required accuracy demands the use of differences higher than the first. Only a very elementary knowledge of the theory of interpolation is required; in the text the most convenient difference formulæ are given, the tables give the coefficients in these formulæ, and several examples are worked to show exactly how the calculations are performed.

Central difference formulæ are used throughout. The coefficients of the Bessel formula are tabled at argument intervals of 0.001, and the coefficients of the Everett formula at intervals of 0.01. In addition very useful critical tables are given. These show the limiting values of the argument, between which a coefficient has a fixed value, and can therefore be used without interpolating for the argument. The range of application of all these auxiliary tables depends, of course, on the magnitude of the differences of the function interpolated. Special attention is paid to this point in the text, and each method described is accompanied by a statement of the conditions which the differences must satisfy for it to be valid.

A novel method introduced is that of the "throwback," whereby a formula requiring high order differences can be reduced to one of lower order. It is noted that as the argument ranges from zero to unity the ratio of the fourth order Besselian coefficient to the second order coefficient never differs much from -0.184 . This suggests the formation of what are termed "modified" second differences M'' , such that $M'' = \Delta'' - 0.184\Delta^{IV}$. It is then shown that, provided fourth differences do not exceed 1000 in the last figure to be retained, it will be possible to use a modified Bessel or Everett formula, where M'' replaces Δ'' and fourth difference terms are ignored. It appears that this method may have wide application. In particular its use would render superfluous the printing of tables with both second and fourth central differences. These differences could be replaced by the single "modified" second differences. An auxiliary table giving $0.184\Delta^{IV}$ for different Δ^{IV} is provided.

Another useful table in the tract under review is one giving directly the second difference term in Bessel's formula. The table is one of double entry, being entered with the argument (at intervals of 0.01) and the sum of the central differences at the end points of the panel (at intervals of 5 in the last

figure retained). This table is useful for performing inverse interpolations, for which a very convenient method is described in the text. With the aid of two Brunsviga machines, calculations often meticulously avoided by scientists become child's play.

Finally, tables of coefficients are given for computing derivatives from differences and for the calculation of differences in sub-divided intervals. A number of useful quadrature formulae are also collected together.

In short, this tract is an extremely useful addition to the apparatus of the trained computer. To scientists of every description, whose work involves reference to mathematical tables, this summary of the most practical methods of interpolation, together with the discussion given of their accuracy, should prove most valuable. The tract is prefaced by Dr. L. J. Comrie, who is well known, both in the scientific and in the commercial field, for his unremitting efforts to reduce to a minimum the tedium of computations of many different types.

B. L. W.

Trigonometry. Part I: Intermediate Trigonometry. By T. M. MACROBERT, M.A., D.Sc., and WILLIAM ARTHUR, M.A. [Pp. x + 206, with 76 figures.] (London: Methuen & Co., Ltd., 1937. 5s. 6d.)

THE authors say that this volume, designed as the first part of a complete text-book on trigonometry, is intended for use in the first-year classes in the universities and in the more advanced classes in the schools.

The scope of the book is best indicated by the titles of the chapters. These are: angles, measurements of angles, arcs, sectors; the circular functions; circular functions of related angles, equations; graphs, inverse functions, area of a segment of a circle; orthogonal projection; addition theorems; transformation of products and sums; the standard linear equation; triangle formulæ; solution of triangles; heights and distances; properties of quadrilaterals.

This list indicates that the subject matter is elementary. The book, however, is comprehensive and more than a mere introduction to the subject. The main text is in ordinary type and the subsidiary matter in smaller type; this keeps the general ideas to the fore, but the subsidiary remarks are important and all deserve to be read by the serious student. One of the chief features of the book is the large collection of worked examples and of unworked examples with answers, these including plenty of "hard" ones for the advanced student.

Were it not that the book is elementary in character one would feel inclined to criticise the presentation of various fundamental parts of the subject where the student is apparently expected to use his intuition. The general impression given by these is one of hurry to get them over "because you can see what is happening anyway."

The writer has painful memories of the gymnastics involved in learning over so many geometrical proofs of the addition theorems, etc., one for every possible case. The authors get round this by using co-ordinates and orthogonal projection to prove the addition theorems and then the allied theorems are deduced algebraically. One fears, though, that examiners are still liable to ask for a direct geometrical proof. This point illustrates a need for some agreement on what can reasonably be expected from the ordinary student in a subject which involves such masses of detail.

Five-figure tables are used, and the authors say that they do not print tables because most readers will find it convenient to use separate sets. Most schools, however, use four-figure tables, so some checking of answers may be needed.

Taking the book as a whole, one feels able to recommend its use by those for whom it is written. Its price is very reasonable; the printing is clear and readable.

J. W. A.

ASTRONOMY

Comets. By MARY PROCTOR, F.R.A.S., and Dr. A. C. D. CROMMELIN, F.R.A.S. [Pp. xi + 204, with 3 plates and 6 figures.] (London: The Technical Press, Ltd., 1937. 8s. 6d. net.)

THIS book retells the story of some famous comets, and sketches the careers of several indefatigable comet hunters. Among the former are those that bear the names of Halley, Encke, Biela, and Pons-Winnecke, while the observers whose methods and achievements are described include Pons, Hind, Denning, Tebbutt, and Barnard. The South Africans, Reid and Forbes, whose discoveries all belong to the last twenty years, are somewhat surprisingly included in the list of "pioneers."

Miss Proctor is responsible for five of the eight chapters. She quotes liberally from various sources, including her father's articles in *Knowledge*, the *Astronomical Memoirs* of John Tebbutt, and papers in the *Monthly Notices* and the *B.A.A. Journal*. Dr. Crommelin has contributed the Preface and Chapters II and III, but, in addition, extracts from his earlier writings are frequently inserted.

The final chapter deals with the problem of the origin of comets. The absence of markedly hyperbolic orbits makes it improbable that they are visitors from interstellar space. R. A. Proctor, over fifty years ago, was the first to suggest that they were born within the solar system and that the giant planets were their parents. This theory is strongly supported by Dr. Crommelin, who considers that the disturbances frequently observed on Jupiter and Saturn, and the variability of light shown by Uranus and Neptune, are evidence that there is still sufficient energy below the cold surfaces of these planets to make good the constant wastage in the comet family.

There is a certain lack of cohesion about the book, and it cannot claim to be by any means a complete account of present-day cometary knowledge, but it makes quite interesting reading.

R. W. W.

SEISMOLOGY

Introduction to Theoretical Seismology. By J. B. MACELWANE, S.J., and F. W. SOHON, S.J. **Part I: Geodynamics**, by J. B. MACELWANE, S.J. [Pp. x + 366, with 67 figures and 15 plates.] (New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd., 1936. 30s. net.)

THIS book may be described as the up-to-date counterpart, in the English language, of Galitzin's classical work *Vorlesungen über Seismometrie* and it should therefore be welcomed by English-speaking seismologists who, hitherto, have had to rely mainly on text-books in a foreign language.

Part II of the book, which was published in 1932, dealt with the theory of the methods now in use for recording earthquakes. Part I is concerned with the mathematics and physics of earthquake waves. In the earlier chapters of this volume the mathematical theory of elasticity and its application to the propagation of waves within and at the boundary of an elastic solid are treated in very great detail. The theory of the reflection and refraction of seismic waves is discussed and there is an account of the methods of deriving the paths of the waves through the earth. The later chapters of the book are especially useful to the practical seismologist; they deal with the interpretation of seismograph records and with the various methods of determining the epicentres of earthquakes. Problems associated with the very important class of shocks that originate at abnormal depths are adequately discussed and a reproduction of the Brunner chart showing times of travel of deep earthquake pulses, on a scale convenient for practical use, is included with the volume.

For the student who wishes to make a serious study of the physical and mathematical aspects of seismology the book can be recommended as being the most comprehensive that has appeared in the English language in recent years. In the introduction the author remarks that a study of the underlying theory of seismology will benefit the geologist; this is very true, but the geologist would need to possess a good mathematical equipment in order to understand the problems dealt with in this book. The book is well produced and well illustrated; there is no lack of references to important original work on the subject and a useful feature is that the full titles of papers are included in the references.

F. J. S.

PHYSICS

The General Properties of Matter. By F. H. NEWMAN, D.Sc., A.R.C.S., F.Inst.P., and V. H. L. SEARLE, M.Sc. Third Edition. [Pp. 427, with 117 figures.] (London: Ernest Benn, Ltd., 1936. 18s. net.)

THE first edition of "Newman and Searle" was published in 1929 and the book has since established itself as one of the standard works on Properties of Matter. The edition under review is described as "revised and enlarged," some extensions having been made (particularly to the chapter on Elasticity), and exercises having been appended to each chapter.

The authors have made a serious attempt to keep the work up to date. For instance, Heyl's determination of the gravitational constant is mentioned, although its importance is rather belittled by its omission from the table of the most credited values of the constant. Milner's treatment of Gibbs' adsorption equation is now included, but the measurement of contact angles—a matter of increasing importance in industry—is still very inadequately dealt with.

However, the authors know best how wide an appeal they wish to make and it is clearly intended to include the mathematician and engineer. The reviewer's own opinion is that the dynamics treated in "Newman and Searle" are more likely to be found in standard works elsewhere than are some of the more physical subjects which the authors omit.

The reduction in price from 25s. to 18s. is a wise step, but the quality of the paper and the general appearance of the book have suffered noticeably.

R. C. B.

The New Chemistry. By E. N. DA C. ANDRADE, D.Sc., Ph.D., F.R.S.
[Pp. 58, with 8 plates and 5 figures.] (London: G. Bell & Sons,
Ltd., 1936. 3s. 6d. net.)

THIS little book gives a vivid descriptive account of modern work on the disintegration of atoms. It is written with the extreme clarity which we have enjoyed in larger works from Prof. Andrade's pen and is enriched by a number of plates depicting the cyclotron and other methods of producing particles with high kinetic energies which can be used to bombard nuclei.

In a witty preface the author declares his intention of providing an account of the recent work on transmutation which may be read by all who have scientific tastes. To all such readers it may be strongly commended.

S. S.

An Introduction to Nuclear Physics. By N. FEATHER, Ph.D.
[Pp. x + 213, with 3 plates and 21 figures.] (Cambridge: at the
University Press, 1936. 10s. 6d. net.)

IN this volume Dr. Feather surveys the enormous harvest of knowledge about the nucleus which has been gathered during the last twenty years. There is perhaps no other subject in which the theory and experiment have advanced so rapidly and in some expositions it is difficult to disentangle ascertained facts from interesting but as yet unverified speculations. This error Dr. Feather has carefully avoided. He first emphasises the phenomenological aspect of each problem and then proceeds to give a brief account of the relevant theories. He has thus provided a valuable introduction and summary of the present state of knowledge, and as such the book will find many readers. There are sections in which one might desire a fuller account of the experiments or a more detailed analysis of the theory, but it must be admitted that the compression and selection which are inevitable in a work of this character have been very judiciously done. Had the author yielded to the temptation to expand the more exciting parts of his theme the book would soon have reached unmanageable dimensions.

Part I reviews the growth of the conception of the nucleus as an entity possessing mass, charge, and structure. The modern picture of a nucleus composed primarily of protons and neutrons and of nuclear processes governed by quantum mechanical laws is built up from the data furnished by studies of radioactivity, mass spectra, and artificial disintegration. Part II surveys in greater detail our knowledge of the stable nuclei, furnished by accurate determinations of nuclear masses, spin quantum numbers, and nuclear magnetic moments. This section contains an account of the interesting results obtained by the molecular beam method which has materially supplemented the information about rotational properties of the nucleus first obtained from an analysis of the hyperfine structure of spectra.

Part III reviews the main results which flow from the study of unstable nuclei; these are grouped under the headings, emission of α -particles, emission of electrons, and emission of quanta. Here is to be found an account of the theories of β -ray disintegration and the neutrino hypothesis of Fermi which is a helpful introduction to this fundamental problem of modern physics. Part IV deals with the very large number of nuclear transformations which have been brought about in recent years by the impact of α -particles, protons, deuterons, neutrons, and quanta of radiation. The types of disintegration processes are classified and the value of measure-

ments of disintegration energies in the accurate determination of nuclear masses is illustrated by a number of examples. The development of the current theories of this new chemistry of nuclei is set out in admirable fashion; it will be highly appreciated by many non-specialists who wish to apprehend the principles which are shaping the development of the modern science of alchemy.

S. S.

Structure of Atomic Nuclei and Nuclear Transformations. By G. GAMOW. Being a second edition of **Constitution of Atomic Nuclei and Radioactivity**. The International Series of Monographs on Physics. [Pp. xii + 270, with 3 plates and 70 figures.] (Oxford: at the Clarendon Press; London: Humphrey Milford, 1937. 17s 6d. net.)

It is five years since the first edition of this book appeared. The increase in size of the work in the present edition is an indication of the mass of new detail which has become available in this short interval. The change in the character of the content illustrates the change in the point of view which has resulted from the new information.

An outstanding feature of the first edition was the account of the author's work on alpha-ray disintegration. That is a part of the subject which has altered very little. In the present work the account is amplified and some formulæ modified, but in the direction of completion, not in the direction of revolution.

One of the chief changes, which is well illustrated by contrast in the two editions, is the discovery by Fermi of a theory of beta-ray disintegration. Five years ago the author wrote five pages on the general features of this process and was perforce content with remarks on the riddles set by the experimenter in this branch of radioactivity. Now we have a complete chapter of nearly thirty pages on the subject, and this is not enough, for the theory is a very remarkable one and is the outstanding contribution to nuclear physics in these five years. It is based on an argument of a very general character. It is true that the idea of proton-neutron and electron-neutrino transitions appear to suggest a very special mechanism and one which to some may be distasteful. This is, however, a mere scaffolding to enable the discoverer to write down equations which, based on an analogy with the quantum theory of radiation, are more general than this detail may suggest.

The author is content to keep very close to the original paper, and this is to be regretted. The reader of a text-book in physics does not require every detail of intermediate steps between one statement and the next, especially when the details are of a purely mathematical character. But a master of the subject loses an opportunity when he strides over many steps, illustrative of the physical aspect of a procedure, with the remark "after some calculation" we obtain the following result.

This applies to the calculation of the total probability of creation of an electron in the course of the account of Fermi's work.

The author, as is well known, is an authority on this branch of modern physics where we are now looking for important developments. He has divided his work into three parts, Stable Nuclei, Spontaneous Nuclear Transformations and Nuclear Transitions by Collisions. The book contains

a careful mathematical presentation of the subject and is full of carefully collected detail. It is not too much to say that it is the most complete account of the subject in English and is indispensable to all workers in this field.

H. T. F.

The Low Voltage Cathode Ray Tube and its Applications. By G.

PARR. [Pp. x + 177, with 76 figures, including 6 plates.] (London : Chapman & Hall, Ltd., 1937. 10s. 6d. net.)

MR. PARR (who is a member of the Radio Division of the Edison Swan Electric Co.) has written a thoroughly practical book on the most widely used form of cathode ray oscillograph. It will serve as an introduction for those using cathode ray tubes for the first time as well as a reference book for the researcher and electrical engineer. The treatment is non-mathematical.

The first two chapters deal with construction and performance of both gas-filled and high-vacuum tubes. We then have a complete chapter on Lissajou's Figures, unusual in such a book but useful. Chapters 4 and 5 deal with various forms of time base circuits, and are followed by three chapters on applications, including television. The scope of these applications may be judged from the titles of some of them : Loud Speaker Response Curves, Dynamic Characteristics of Valves, Ionosphere Observations, Explosion Pressures, Measurement of the Velocity of Sound, The Electrocardiograph. A few slips have crept in, but they are relatively unimportant and can easily be corrected in the next edition. There is a short appendix on photographic recording and a most valuable classified bibliography of over 400 references. For some workers the bibliography alone will be worth the price of the book. The illustrations are good and the paper will withstand rough handling in the laboratory.

The cathode ray oscillograph is becoming of great importance as an instrument of research and we are glad to recommend this clear introduction to its use.

F. A. V.

Thermodynamic Properties of Steam. By JOSEPH H. KEENAN and

FREDERICK G. KEYES. [Pp. 89, with 10 figures.] (New York : John Wiley & Sons, Inc. ; London : Chapman & Hall, Ltd., 1936. 13s. 6d. net.)

THESE new American steam tables are constructed on an entirely new basis from the old Keenan tables. In the former case the values were arrived at by graphical interpolation of the best available steam data, but for their new tables Profs. Keenan and Keyes have constructed an equation of state, from which they can calculate the required properties of superheated or saturated steam. This is the same method as used by the late Prof. Callendar for the British steam tables, and also by Prof. Mollier for German tables, but the new American equation is very different from those of Callendar and Mollier, and would, it is to be feared, cause first-year students some trouble. The use of an equation of state in the formulation of steam tables has the advantage that the derived quantities are thermodynamically consistent, and thus values such as the Entropy, at any particular pressure and temperature, can be calculated directly without troublesome integration of heat differences.

The constants used for their equation are based on what they consider

the best available steam data, but to obtain a function to represent the specific heat of the vapour at zero pressure they have turned to quantum mechanics. As regards the lay out of the tables themselves, the horizontal temperature co-ordinates do not seem quite so easy to read as the vertical temperature scale in the British tables. Also the American arrangement allows for less than half as many temperature points at any given pressure, and the result of this smaller number of points is that several changes in the temperature interval occur, so adding to the difficulty of rapid interpolation of intermediate values. The only other criticism, of what is undoubtedly a very accurate steam table, is of the title itself, which seems to suggest a weighty text-book rather than a plain steam table.

G. S. C.

An Introduction to Fluid Mechanics. By ALEX. H. JAMESON, M.Sc., M.Inst.C.E., F.K.C. [Pp. x + 239, with 116 figures.] (London, New York, Toronto: Longmans, Green & Co., 1937. 7s. 6d. net.)

Few branches of applied science have developed more rapidly within the last twenty years than that dealing with the mechanics of fluids. Only a few years ago, as the author remarks, the subject was in a most unsatisfactory state, being subdivided into Hydrodynamics and Hydraulics. The former dealt mathematically with a perfect fluid in which viscosity and friction were absent, and hence had little meaning for the engineer. On the other hand, the subject of Hydraulics, as studied by engineers, consisted to a large extent of empirical formulæ and tables of coefficients.

Much research is at present being directed to linking these branches of the subject, and this is being assisted to a marked extent by the rapid development of aerodynamics. Possibly the greatest assistance in correlating these various branches of the science has come from the use of dimensionless analysis.

The book now under review is an introduction to the subject treated on the most general lines and the author has taken full advantage of the new methods. Examples of the use of dimensionless analysis include its application to the flow through an orifice, the resistance of a smooth pipe and that of a submerged body.

The section on the flow in rough pipes includes some of the most recent work of Prandtl and von Kármán.

The author's aim is to cover the syllabus for Part I of the B.Sc. (Engineering) examination of the University of London. To this end there is included an introduction to the theory of circulation and vorticity. In spite of the simple treatment given, it is questionable whether this subject is not beyond the grasp of the average second-year student.

An excellent feature of the text is the number of "guided" examples, which give it the hallmark of the real teacher.

In view of the clear treatment of the subject it is to be hoped that the author may be tempted to write a second volume to cover the syllabus for Part II of the examination and that this may develop on the same broad lines.

B. J. L. E.

Hydraulics. By CHARLES W. HARRIS, C.E., M.Am.Soc.C.E. [Pp. xiv + 220, with 132 figures.] (New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd., 1936. 13s. 6d. net.)

THIS hardly lives up to the claim in the preface to present the modern outlook on Hydraulics. On the whole it is rather an elementary text-book closely following the older treatments. One feels that it was probably written to accompany a lecture course for the author's own junior students, and no doubt it serves that purpose; otherwise it is difficult to understand why it should have been written.

The treatments are elementary in the sense that they evade elementals, and most are less complete than those in older books; the phrasing and general presentation are often poor. Nor has the author sufficiently verified the numerical matter; for example (p. 50), a weir coefficient is given as 4.0, with a statement that this is experimentally supported by numerous workers, whereas in fact this value is as much as 25 per cent. in error over most of the range concerned.

It is altogether too superficial even for beginners, for it will leave their difficulties unanswered, even assuming they have the patience to wade through such obscurities as (p. 104) "Care should be exercised in demanding the method of constant Reynolds number. This law of resistance to mobility—," or such misleading futilities as (p. 130) "Oil has a reasonable viscosity and is carried in mains that are reasonably smooth when installed and tend to be preserved in that condition by a favourable content."

C. M. W.

CHEMISTRY

Inorganic Chemistry: A Survey of Modern Developments. By SIR GILBERT T. MORGAN, D.Sc., Sc.D., LL.D., F.R.S., and F. H. BURSTALL, M.Sc. [Pp. x + 462, with 16 figures.] (Cambridge: W. Heffer & Sons, Ltd., 1936. 15s. net.)

MANY chemists, having enjoyed the foretaste given by the senior author in his lectures to the Institute of Chemistry four years ago, will turn to this amplified presentation of their subject matter with a lively expectation of refreshment. They will not be disappointed. This book stands clearly apart from the general run of text-books because it is not a treatise: while it covers the whole field of inorganic chemistry, it deliberately omits what every chemist knows and, as the sub-title indicates, deals with just those matters which are relatively new and of special importance and interest. In a word, it presents modern non-organic chemistry with all the dull stuff left out. Moreover, the authors take a properly generous view of their field, so that the reader, surfeited with adjectival chemistry for adjectival chemists, has a deep sense of satisfaction in following their exposition of chemistry as a whole; a mass of facts, it is true, but all linked and lighted by the fundamental generalisations and especially by the electronic conception of valency.

Although the book is no bigger than the average novel (and a deal more readable than most) the choice and arrangement of matter is so skilful and the writing so tight and clear that space is found for unusual and very useful features. Of these, two deserve special mention: a system of references by name and year which effectively keys the narrative to the original literature, and a lavish use of graphic formulæ which are peculiarly valuable in enabling

the authors to demonstrate throughout the book the far-reaching significance of the theory of co-ordinate linkage. There is, indeed, so much good material in the book that no brief review can possibly give an adequate idea of its content. Some sections, however, merit special praise; for example, an excellent outline of the experimental basis of current atomic theory, a rather full account of deuterium and its compounds, and the admirable chapters dealing with natural and induced radioactivity, with inter-metallic compounds and with the organic derivatives of the metals and metalloids.

Advanced students appreciate this book because it gives them in a readily assimilable form all the points in which their examiners are likely to be interested, but its fame will rest, we believe, on the fact that the average practising chemist, who realises that chemistry is rushing past him but finds his efforts to keep up defeated by the bulk and complexity of chemical literature, has here a sure and pleasant road to salvation. Reading it, as time serves, in the train or in his bath, he will gain a well-founded sense of knowing the things he ought to know and wants to know.

The book is remarkably free from errors, and the printers, no less than the authors, are to be congratulated on the accuracy they have achieved in a lot of difficult type-setting. There are good author and subject indexes. As an attractive, precise and luminous account of what matters most in general chemistry, it must be strongly commended to all kinds of chemists in all stages of growth or decay.

H. V. A. BRISCOE.

Gmelins Handbuch der anorganischen Chemie. 8. Auflage. Herausgegeben von der Deutschen Chemischen Gesellschaft. System-Nummer 22: **Kalium**, Lieferung 1-3; System-Nummer 23: **Ammonium**, Lieferung 1 und 2; System-Nummer 36: **Gallium**; System-Nummer 37: **Indium**. (Berlin: Verlag Chemie, G.m.b.H., 1936-37.) Kalium. [Pp. vi + 804, with 35 figures.] RM. 95.25; Ammonium. [Pp. xviii + 618, with 65 figures.] RM. 72.35; Gallium. [Pp. xviii + 104, with 8 figures.] RM. 13.87; Indium. [Pp. xviii + 120, with 8 figures.] RM. 15.75.

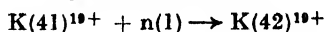
In the first review¹ of the new edition of the monumental *Gmelins Handbuch* its general character was outlined and reference made to the outstanding merits of the work. One disadvantage mentioned was, however, its incompleteness. It is, therefore, with special pleasure that we welcome the rapid progress since made. No less than five additional sectional volumes have come to hand, devoted to the elements potassium, gallium, indium, and the group NH_4 .

Three part-volumes dealing with the element potassium have so far appeared. The matter is subdivided exactly in the same way as are the elements previously treated in Gmelin—which makes it all the easier for the reader to find the paragraph in which he is interested; the comprehensive index, added on loose leaves to each section, gives further assistance. But although the headings of the chapters and sub-chapters throughout Gmelin follow the same strict rules, their respective matter-content of course varies widely in extent. To point out some chapters which are especially prominent in the potassium volumes we may perhaps draw attention to the very thorough survey of the geological occurrence of this element. Van't Hoff's

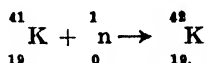
¹ SCIENCE PROGRESS, XXXII, 168 (1937).

and his pupils' work on the laws governing the crystallisation of potassium minerals in the famous deposits in Germany and in a few other parts of the world are very clearly summarised and make interesting reading. Here, as well as in other volumes of Gmelin, maps and diagrams are frequently used.

Another chapter in which the thoroughness of the contributors is very impressive is the one dealing with the nuclear reactions of potassium; its natural radioactivity as well as the artificial transmutations are fully discussed. Here, however, one small criticism cannot be suppressed. In writing nuclear disintegrations it is advisable to follow the custom introduced by radiologists into physical and chemical literature—namely, writing the nuclear charge as a subscript, and the atomic weight as a superscript, on the left side of the atomic symbol. The equation which describes the addition of a neutron to the potassium nucleus :



is clumsy and unusual. The conventional form, now almost universally accepted, would read :



For the sake of consistency it is desirable that Gmelin should henceforth always indicate the atomic weight of an isotope by a left-hand superscript, and not by a bracketed figure following the symbol, as has hitherto been its habit.

Other chapters of great interest to physical chemists, less fully dealt with in other inorganic handbooks, are those on "discoloured" potassium chloride and bromide; the description of the preparation and of the optical and electronic properties shown by these abnormal compounds fills about 17 pages.

The group NH_4 is discussed much in the same way as the alkali metals; its occurrence in nature, the fruitless attempts to prepare it in the form of a free radical, the chemical and electro-chemical behaviour of the ammonium ion and the compounds with other elements are carefully treated. The enormous practical importance of ammonia salts becomes evident in the chapters dealing with fertilisers; here one of the grimmer aspects of chemistry is revealed by the short statement that at Ludwigshafen on September 1921 an explosion of ammonium sulphate-saltpetre killed 586 people and wounded 1952.

Comparatively meagre are the volumes dealing with the elements gallium and indium, the first containing "only" 100, the second 116 pages. Since even the extraordinary zeal of the Gmelin staff has not been able to fill as much as a page with records of the practical applications of either element, and as their inorganic and physical chemical examination has been hampered by their extreme rarity, the most voluminous chapters are devoted to the analytical chemistry of these rare substances. Full details and diagrams are given of those alloys which have been thoroughly investigated.

It is obviously impossible and at the same time, we are sure, unnecessary to give more than a few examples of the enormously rich content and incomparable reliability of these new Gmelin volumes. It can certainly be said that the unique standard attained by previous issues has been fully maintained. If a slight criticism may be uttered it refers to the somewhat grey print of several pages; as the printing, for obvious reasons, is in rather

small type it is all the more necessary that care should be devoted to securing a thoroughly black impression; but possibly the greyness of the reviewer's copy is merely an exception.

It may be of interest to mention that on the basis of last year's publishing effort the chemical world may look forward to the completion of the whole Gmelin work in the year 1943. To achieve this result some 2200 closely printed pages must be produced year by year. As a somewhat larger quota has been attained during 1936, there is every prospect that the 56 members of the permanent staff, and their external collaborators, will succeed in reaching the desired goal. Already the help this German handbook offers to chemists of every country is incalculable.

F. A. P.

Structure and Molecular Forces in (a) Pure Liquids and (b) Solutions: a General Discussion held by the Faraday Society, September, 1936. [Pp. 282, with numerous figures.] (London: Gurney & Jackson, for the Society, 1937. 12s. 6d. net.)

SYMPOSIA on subjects of scientific research tend to suffer, as reading material, from one of two faults. If the subject is of very recent development, the discussion may produce so many unanswered questions as to leave the non-expert confused and the expert impatient. If it is one that has settled down into a phase of consolidation, we may have the dullness, without the completeness, of a work of reference. In the present case we have an extremely good balance between these extremes. The volume, though containing 33 original papers and fully reported discussions of them, is very moderate in length and eminently readable.

Two reasons for this satisfactory position are apparent. Firstly the discussion is confined by boundaries of method rather than of subject matter. A discussion on the whole of one of the states of matter would not have been possible had not the properties it was sought to explain been for the most part the normal properties of simple materials. Secondly, while the methods of approach may be the fulltime study of those who describe them, their application to liquids and liquid solutions is in most cases a recent extension from other fields. As a result, a community of purpose greater than usual is evident.

Perhaps the most important recent development dealt with is that permitting the word "structure" in the title. A geometry of liquids is being created. One feels that the modern problem is to explain, not why a liquid is not a gas, but why it is not a solid. Bernal's theoretical attempt at a "molecular theory of liquids" and the papers of Frenkel and Simon provide a very interesting discussion of this problem. Under the guidance of Prins, Magat, Errera and others, techniques such as X-ray and electron diffraction, Raman and infra-red spectra are throwing their light on the internal arrangement in liquids.

London's summarising paper on his theory of molecular forces is particularly welcome. Various aspects of dipole interaction and of hydrogen and hydroxyl bonds are also discussed, principally in the solutions section. In this section some very good summaries of recent experimental data are presented, on vapour pressures, volume changes, heat of mixing, solvation and arrangement of ions in solution, on diamagnetism and refraction.

G. S. H.

Absorption and Extraction. By THOMAS K. K. SHERWOOD. McGraw-Hill Chemical Engineering Series. [Pp. viii + 278, with 91 figures.] (New York and London: McGraw-Hill Publishing Co., Ltd., 1937. 21s. net.)

PROF. SHERWOOD's book is a veritable mine of information to those having to deal with absorption problems. It is particularly valuable in that the physico-chemical principles underlying absorption processes in general are adequately dealt with. In the past it has often been evident that absorption plant has been developed by intelligent, but nevertheless, empirical methods, and that no striking developments in design and efficiency have been possible until the fundamental physico-chemical data underlying the process have been appreciated. Prof. Sherwood has summarised such data very clearly and critically, at the same time giving an extensive bibliography. Technical men in other industries may perhaps regret that the absorption of nitrous gases is the only industry dealt with in practical detail, but the limitations of space will obviously prevent the inclusion of critical and descriptive detail concerning absorption processes in a number of different industries. Nevertheless, it would have been interesting, while treating the acid industry in detail, to have included a discussion on the absorption of acid "mists" which involves special physical considerations. The absorption of gases by liquids is distinctly the better part of the book, but Prof. Sherwood is to be congratulated on making a sweeping advance in clarifying the problems of absorption as a whole, and so making it easier for the chemical engineer to design such plant on a scientific basis.

HARRY W. WEBB.

Chemicals in War: A Treatise on Chemical Warfare. By AUGUSTIN M. PRENTISS, Ph.D. With chapters on "The Protection of Civil Populations" and "International Situation," by GEORGE J. B. FISHER. [Pp. xviii + 739, with 141 figures and 19 charts.] (New York and London: McGraw-Hill Publishing Co., Ltd., 1937. 45s. net.)

It is evident that any description of chemical warfare written at the present time must be either entirely historical or mainly surmise. The nations do not pool their knowledge in these matters and even the English-speaking peoples do not let one another know the progress and advances which are, presumably, being made in this field. The book under review deals, therefore, with the condition of the subject immediately after the War and it is from this point of view that its value has to be assessed.

The new knowledge, if there is any such, is hidden in the War Office files of the various nations, and, although rumours are heard of new discoveries each more startling and more frightful than the last, there is no means by which the truth of such rumours can be determined. The only method is for each nation to carry out research in order to find if new substances exist and if so what value they possess. For unless research into the existence of such materials is continuous and intense how is it possible to tell the nature of the evils against which we have to protect ourselves? And unless experiments on the quantitative evaluation of a substance are carried out under practical conditions, how can it be ascertained what order of protection is needed?

The book under review is divided into five parts. Part I is devoted to an exposition of the fundamental principles underlying the science of chemical warfare. Part II presents the "materia chemica" of war. Part III is

devoted to the technique and tactics of chemical warfare by the several arms, and traces the evolution and development of the use of chemicals in battle from the early World War period to the present day. In Part IV protection against chemical warfare is considered, not only from the military viewpoint, but also as applied to the civil population, at least a part of which will undoubtedly be subjected to chemical attack in future wars. Part V treats of certain general aspects of chemical warfare such as: its relation to the chemical industry; its effectiveness in war, and its use in the past. The concluding chapter sums up the arguments for and against the use of chemicals in war.

The subject matter is marred by several inaccuracies and many misprints. It looks as if the proofs had been read by someone without chemical knowledge, for surely no chemist could pass the formula BaNO_3 without comment. On the whole the reading matter is good, although the author is careful to disclaim any official sanction for the views he puts forward. Nevertheless, the views and comments of George J. B. Fisher on the protection of the civil population seem sound and are well expressed. This question is of a highly complex nature, and is psychological as well as physiological; for the attacker is likely to rely just as much on panic as on the actual infliction of injury. Absolute protection from injury is, of course, not possible; protection can only be relative. The most that can be done is to give protection against what may be regarded as "normal conditions," meaning thereby the kind of danger that is to be expected from a normal attack. It is not possible to provide protection against abnormal circumstances such as would be produced by a direct hit or by a bomb entering the living-room by way of the chimney. It is fortunate that comparatively high concentrations of gas are difficult to produce in the open and that both time and concentration are matters of urgent moment. Moreover, open spaces even in densely populated cities are many times larger than those actually occupied by dwellings.

The book will serve a useful purpose if it merely shows that the use of chemical substances in warfare constitutes a real menace which must be met by adequate protection. Time alone will show the real measure of this menace, although there are some who hope that a potential enemy may be induced to make use of it against civil populations rather than to employ the alternative of high explosives. One thing is certain, namely that chemical warfare has come to stay as long as the curse of war persists. Moreover, the manufacture of chemical warfare materials is unlikely to be restricted by any form of international agreement owing to the close relationship the production of such material bears to the normal process of chemical industry.

J. F. T.

Cyanidation and Concentration of Gold and Silver Ores. By JOHN V. N. DORR, E.M., D.Sc. [Pp. x + 485, with frontispiece and 135 figures.] (New York and London: McGraw-Hill Publishing Co., Ltd., 1936. 30s. net.)

THE cyanide process for the extraction of gold from its ores was patented 50 years ago, and it is worthy of note that, although considerable improvements have been made in technique, the process remains substantially in the form in which it was first established.

Expressed in its simplest form the process consists in dissolving out the gold from the ore in a weak cyanide solution, and precipitating the dissolved

gold from this solution by means of metallic zinc, after filtering off the undissolved barren mineral matter with which the gold was originally associated. In view of the intrinsic simplicity of the process from the chemical standpoint, the problems involved in its application on a large scale are mainly those of engineering, and the perfection of each of the three basic operations of solution, filtration and precipitation, with their adaptation to the treatment of ever-increasing tonnages of ore and solution have occupied the attention of metallurgists and engineers since the inception of the process, which is now carried out upon an enormous scale, a modern plant treating as much as 10,000 tons of ore per day.

The work under review deals in an admirably clear and concise manner with the process as carried out to-day, each stage being considered both theoretically and practically. After a brief historical introduction, chapters are devoted in succession to coarse crushing, fine grinding, classification, sand and slime treatment, and recovery of bullion. Concentration of ores containing base-metal sulphides, both by gravity and flotation, the latter a comparatively new adjunct to the treatment of gold ores, is discussed in detail. A valuable section of the book describes the treatment of simple and complex ores by reference to existing plants in all the important gold-fields of the world, illustrated by numerous flow-sheets and a wealth of statistical data, drawn both from the author's wide experience, and from the leading technical literature. Plant control, costs, and power consumption are also dealt with in considerable detail.

The work as a whole presents an admirable picture of present-day cyanide practice, and should prove a reference book of the greatest value on all phases of the subject.

B. W. D.

Bearing Metals and Alloys. By H. N. BASSETT. [Pp. xiv + 428, with 9 plates and 9 figures]. (London: Edward Arnold & Co., 1937. 25s. net.)

THE author of this volume is the Chief Chemist of the Egyptian State Railways and was formerly Senior Assistant Analyst of the Great Western Railway. There is a foreword by Sir Henry Fowler, in which he points out that, of all the minor points of engineering, none is of more importance than the bearings.

In the introductory and historical chapter the development of bearing metals is outlined and a bearing is defined as "a means of supporting a shaft or other moving part, and a bearing metal is one with which the bearing is lined or of which in some cases it is made, the composition being chosen to cause the minimum amount of loss of power by friction in the bearing."

The lubrication of bearings is dealt with and the operating conditions, oiliness, seizing and effects of lubricants on bearing metals, etc., are discussed. A useful chapter is devoted to bearing metals in general, in which different classes are discussed and preliminary observations on the structures are made, leading to the theories of these metals, in connection with which the views of the school insisting that only a heterogeneous metal will serve for bearings and of the school maintaining that a homogeneous metal will work perfectly well are put forward, and it is pointed out that the bulk of the bearing metals now in use are of the heterogeneous class.

As is to be expected, the various alloys known as white antifriction metals are dealt with very fully, and not only are lead-base and tin-base metals

described, but the effects of additions of other metals are given, and the effects of mould and pouring temperatures on the various mechanical properties are discussed, together with the properties at elevated temperatures and the effects of remelting and segregation.

Chapters are devoted to copper alloys used as bearing metals, including zinc bronzes, lead bronzes and phosphor bronzes.

In the final chapter on miscellaneous bearings, cadmium-base, aluminium-base, magnesium-base and zinc-base alloys are dealt with, together with beryllium copper, graphited bearing metals, cast iron, compressed powder bearings and fabric, rubber, wood and stone bearings.

An appendix is devoted to the micro-examination of bearing metals, in which details of preparation of the chief classes of alloys are given for microscopical examination and for photographic records for the measurement of grain size.

A second appendix deals with the uses of bearing metals and includes a table showing the composition of recommended alloys for different types of bearings.

The book contains an enormous amount of information which will prove of great value to engineers; the various points are made clearly and concisely and references are included throughout the chapters which will make it easy to consult the original work implicated.

C. O. B.

Chemistry of Food and Nutrition. By HENRY C. SHERMAN, Ph.D., Sc.D. Fifth Edition. [Pp. xii + 640, with 38 figures.] (New York and London: Macmillan & Co., Ltd., 1937. 12s. 6d. net.)

PROF. SHERMAN's book on the chemistry of food and nutrition is so well known and so well recognised as a standard work on the subject that little more is necessary than to announce, by way of review, that a new edition has appeared. When one realises that this fifth edition is completely rewritten, ordering a copy becomes automatic.

The book certainly is rewritten and has come still more alive in the process. Prof. Sherman has moved out into the market-place although he still maintains in his opening sentence "Chemistry is the central science." The chemistry of the subject still holds in the book the central position, but Prof. Sherman's standpoint has become, or perhaps we should say he has allowed it to appear, more human than in the older editions. He quotes with approval the distinction made by the American Medical Association between "buoyant health" as compared with "merely passable health" and is clearly of the opinion that the function of the worker in nutrition is not so much to discover and describe the mineral needs of the human body in food but the optimal diet. He realises that it is still true for the majority of the world's people that "Half the struggle of life is a struggle for food."

None the less the truly chemical aspect of the subject is well up to date and the student of the subject, together with those who appreciate and put into practice the discoveries of the chemist, will find the book an invaluable *vademecum*. Particular attention is called to the collection of statistics concerning the amounts of vitamin A in some 75 common foods. Similar tables for flavin values are given. May we hope in the next edition for similar tables for vitamins B₁, C and D?

Two additional chapters on Food Economics and on Food Chemistry and

Human Progress form a coda to the book and show the direction in which Prof. Sherman's mind is moving.

His book can be warmly recommended to all interested in nutrition.

V. H. M.

The Biochemistry of the Lipids. By HENRY B. BULL, Ph.D. [Pp. x + 169, with 63 figures.] (New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd., 1937. 13s. 6d. net.)

THE term "lipid" is used by Dr. Bull in a very comprehensive sense, and the scope for this little monograph is indicated by the fact that it is based on Bloor's classification of lipids into simple (fats and waxes), compound (phospholipids such as lecithin and cephalin; cerebrosides), and derived (fatty acids, sterols, higher alcohols) lipids. Hence the treatment of the individual topics is rather scanty and superficial, but the text is liberally embellished with references, including numerous citations of review articles. The book is by no means free from serious inaccuracies and cannot be recommended as a reliable guide for elementary students, but advanced students and research workers will find in it an interesting and readable account of a very wide range of unexpectedly diverse phenomena. There are intelligible accounts of the physical problems involved, as well as descriptions of the biochemistry and structural chemistry of the lipids, and brief mention is made of their importance in physiology and pathology. Erroneous statements appear throughout the book, and the reviewer was particularly conscious of those in the chapter on sterols; for instance, it is stated that bacteria can bring about the conversion of coprostanol into coprostane, cholanolic acid and the bile acids. Another remarkable statement appears in the section on carotenoids, to the effect that the colour of these seems to be dependent upon the two ring structures. The chapter on fats and oils includes an account of the important work of Hilditch on the analysis and distribution of natural glycerides, and also deals with synthetic glycerides, fat metabolism, hydrogenation, rancidity, drying oils and auto-oxidation.

J. W. C.

Annual Review of Biochemistry. Vol. VI. Edited by JAMES MURRAY LUCK. [Pp. ix + 708.] (Stanford University P.O., California: Annual Review of Biochemistry, Ltd.; London: H. K. Lewis & Co., Ltd., 1937. \$5.00.)

AN adequate review of this volume of 708 pages containing 28 articles would occupy many pages of SCIENCE PROGRESS. In the brief space available it is not possible to do more than notice one or two of the novel features of this, the sixth volume of the series. The vast majority of biochemists are already familiar with the earlier numbers, and fully appreciate their great value in providing an authoritative and at the same time readable survey of recent progress in the Science. Up till now, however, the books have suffered from one great disadvantage—the lack of a subject index. In the present volume this defect is remedied and all readers will rejoice. The Editors are to be congratulated on having overcome the practical difficulties which stood in the way of this improvement. Those who possess the earlier volumes, which lack a subject index, will look forward to the Cumulative Index, which the Editors hint in their preface will be published in due course. These volumes aim at covering not only the standard and orthodox subjects

of biochemical research but also the less familiar, perhaps somewhat specialised, but sometimes very interesting and important topics related to the main themes. The present volume, for instance, includes an article by T. A. Bennet-Clark on the organic acids of plants; by R. Emerson on Photosynthesis; by C. M. McCay on the biochemistry of fish; by A. J. Quick on detoxication mechanisms; and by P. L. Kirk on the application of microchemistry to biochemical analysis. Apart from these special topics the ordinary staple material of biochemical investigation, proteins, carbohydrates and fats, enzymes, vitamins, sulphur metabolism, the biochemistry of plants and the like receive able and comprehensive treatment. This volume, like its predecessors, is invaluable to all directly or indirectly interested in biochemistry.

W. O. K.

The Chemistry of Natural Products Related to Phenanthrene.

By L. F. FIESER. American Chemical Society Monographs No. 70. [Pp. xii + 358.] (New York: Reinhold Publishing Corporation; London: Chapman & Hall, Ltd., 1936. 32s. 6d. net.)

For many years morphine and the related alkaloids codeine and thebaine were the only important naturally occurring compounds known to contain the phenanthrene ring system but the last decade has seen the addition to this class of an amazing number of natural products of great variety and importance. From rosin there has been obtained a transformation product abietic acid which on dehydrogenation gives retene or 1-methyl-7-isopropylphenanthrene. The sterols and bile acids have been found to contain a reduced phenanthrene ring system with a cyclopentane ring fused on to it and these compounds are closely related to vitamin D, the sex hormones, the heart poisons from plants such as digitoxin and the poisons from toad venom such as bufotoxin. Again the saponins in certain plants are derivatives of phenanthrene and the cancer producing hydrocarbons found in tar oils are closely allied compounds.

The output of research in these fields is enormous and most of it is of quite recent date, some idea of its volume can be gained from the author index of this work which includes 767 individual names.

Prof. Fieser has surveyed the work published up to February 1, 1936, in a very thorough manner and his book is particularly valuable in that it collects together in one volume the chemistry of a number of compounds structurally related but differing sufficiently in biological function to be divorced from one another in many monographs. It will appeal especially to the organic chemist for, although short accounts are given of the biochemical aspects of the compounds, it is not overloaded with detail in this respect and deals essentially with the elucidation of the structure of the compounds and with their synthesis. The book can be warmly recommended to those especially interested in the chemical aspect of the subject.

O. L. B.

Organic Syntheses, Vol. XVII. Editor-in-Chief L. F. FIESER. [Pp. vi + 112.] (New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd., 1937. 8s. 6d. net.)

This valuable series continues serenely on its determined course of describing tested laboratory methods for preparing in good quantity organic compounds

required for research and other purposes. Thirty substances are dealt with, among which one may mention γ -aminobutyric acid, ϵ -aminocaproic acid, *p*-bromobenzaldehyde, 1:3-butadiene, dihydrocholesterol, ethyl methylmalonate, α -phenylethylamine and triphenylethylene. There is the customary appendix containing later references to preparations in the preceding volumes.

O. L. B.

Synthetic Rubber. By W. J. S. NAUNTON, M.A., M.Sc., Ph.D. With an Introduction by PROF. SIR WILLIAM J. POPE. [Pp. xvi + 162, with 13 plates and 20 figures.] (London: Macmillan & Co., Ltd., 1937. 7s. 6d. net.)

THIS is the first book to be published which deals with both the economic and technical as well as the chemical aspects of the subject. Dr. Naunton is the Head of the Rubber Laboratories of Imperial Chemical Industries Ltd., and can speak with authority upon the change in the industrial and economic aspect so far as the production of synthetic rubber is concerned.

The book deals with the history, economics and the future outlook of synthetic rubber and traces the history of synthetic rubber from the early academic period to the present time when it is realised that only by improving upon the natural product can the synthetic product meet with commercial success.

The chemistry of synthetic rubber is discussed, but mainly in connection with neoprene. The results of tests, as for instance, the oil resistance, are given in the form of graphs.

The first portion of the book is based upon lectures which the author has given and if any criticism can be levelled at the publication, it is that the author would probably have avoided certain repetitions if he had discarded his lecture notes and written the book so that the subject is more flowingly developed. Some of the diagrams are also unsuitable for book publication, but admirably adapted to lecture purposes. The book is stated to be of interest to the lay reader, but the inclusion of chemical sections and references throughout the book make it highly improbable that the lay reader will follow as easily as if all the chemical aspects had been brought together more or less in one chapter, which he would have skipped.

Finally it is regrettable that the excellent photographic illustrations in the book appear to have little corresponding text matter. The description of the method of manufacture of some of the synthetic rubbers is surprisingly brief.

T. J. D.

The Accelerated Vulcanisation of Rubber. By TORBJÖRN GRENNES, Diplom. Engin. (Chem.). Translated by MONICA STORM GRENNES and ALEXANDER C. JARVIS, M.Eng.F., M.I.Mech.E. [Pp. 120, with 56 figures, including 1 plate.] (Copenhagen: Levin & Munksgaard; London: Williams & Norgate, Ltd., 1937. 10s. 6d. net.)

THIS is a treatise submitted by the author to the Royal Technical College in Copenhagen for the Degree of Doctor Technices, and records the author's investigations and critical survey into various aspects of rubber vulcanisation accelerated by means of dithiocarbamates and thiuram sulphides.

The thesis is divided into three main sections (a) a summary of twelve pages giving the various theories on the reactions of accelerators especially

dithiocarbamates and thiuram sulphides; (b) a record of physical and chemical investigations under five headings and occupying 95 pages; and (c) a brief report of four pages on the practical application of the use of glue in rubber compounds.

The second section records the author's investigation and is given under five headings. (1) *Technique*.—This chapter is devoted largely to a discussion and development of a new method for determining resistance to tear. The results are extremely interesting as it is shown that a characteristic constant may be obtained which represents the resistance to tearing and which is dependent only on the rubber mix employed and is independent of the dimensions of the test piece. It is possible that some rubber technologists will not be prepared to accept the author's deductions. (2) *Related Accelerators*.—In this chapter is recorded the experimental results obtained by using equivalent amounts of related accelerators such as the amine dithiocarbamates, metallic dithiocarbamates, and thiuram sulphides and the author's deductions therefrom. (3) *Influence of Metallic Oxides*.—Then follows a short chapter recording the influence of cadmium, lead and zinc oxides on the accelerators and the suggestion that improvements on the present method are possible. (4) *Influence of Protein (Glue) and Water*.—The author describes experiments on the effect of glue on the tensile strength, elongation, permanent set, swelling and hardness of a rubber mix. The influence of water is also studied and in (6) *Summary*, the author briefly reviews the preceding chapters.

The book records original investigations and covers a wide range and will undoubtedly be of great interest to research workers on problems connected with rubber vulcanisation and physical testing.

T. J. D.

Canning Practice and Control. By OSMAN JONES, F.I.C., and T. W. JONES, B.Sc. [Pp. xii + 254, with 74 figures, including 65 plates.] (London: Chapman & Hall, Ltd., 1937. 25s. net.)

THE history of canning begins with the invention by a Frenchman, Nicholas Appert, of a method of preserving foodstuffs by sealing them hermetically in containers in a sterile condition; this invention was stimulated by the offer of a prize by Napoleon the First for the discovery of a means of preserving food so that it could be kept without decomposing and could be readily transported. Thus it was a war-time invention. The need for preserved foods was, of course, very marked during the Great War and since that time the canning industry in this country has made great strides, encouraged and assisted in many ways by the Department for Scientific and Industrial Research. In the preface the authors describe canning as "filling the metal container with food and sauce, syrup, soup, brine or gelatine, exhausting it of air, sealing on a lid, sterilising and cooling." Every aspect of the subject is touched on such as the can, the solder, rubber seals, water supply, laboratory organisation, chemical and bacteriological examination, cannery waste, etc. A very considerable portion of the book is devoted to the microbiology of canning in all its branches with full details of how to carry out the experiments. The instructions given are lucid and explicit and reliable and should be of great assistance to workers in this field. The book contains under one cover much that is not otherwise easily accessible. A number of misprints of author's names have been noted but these are minor blemishes which can be corrected in a future edition and do not in any way detract from the value of the book.

P. H.

Quantitative Organic Microanalysis of Fritz Pregl. By DR. HUBERT ROTH. Third English edition translated from the fourth revised and enlarged German edition by E. BERYL DAW, B.Sc., A.I.C. [Pp. xvi + 271, with 72 figures, including 1 plate.] (London: J. & A. Churchill, Ltd., 1937. 18s. net.)

THE output of microchemical literature has increased considerably since the late Fritz Pregl was made Nobel Laureate for his pioneer work in the field of quantitative organic microanalysis. Even in that special field much new and important technique has been elaborated by Pregl's pupils and others, as is evident from the contents of the Fourth German edition of his book in which we find the latest improvements on the original Pregl methods together with additional determinations such as those of amino-acids, — NH_2 (van Slyke), active H, acyl, isopropylidene, Me attached to C, double bonds by catalytic microhydrogenation, molecular refraction, absorption spectra (Pohl). If the new German text is as accurate and painstaking as the previous ones from the pen of Pregl himself, one must deplore the inferiority of the present English version of it. Not only is the translation often ambiguous or obscure, but there are many mistakes. Some of these show careless proof-reading, others suggest lack of knowledge of the subject on the part of the translator. These are unpardonable faults in a book which is indispensable to the daily practice of the analyst who, if he is experienced, has learned to expect and to obtain the highest standard of reliability in microchemical publications. It is not possible here to catalogue every detail to which the reviewer takes exception (there are about a hundred of them), but it is necessary to point out some of the worst examples. Among the clumsy renditions are—p. vi, line 5, "the determination of general groups of natural products"; line 30, "the enlargement of range through the additional method"; p. 15, line 11, "To control the necessary conditions with certainty was made possible in excellent ways"; p. 28, line 13, "pieces of pumice stone at boiling point"; p. 71, line 32, "the stopcock of the intermediate pieces"; p. 81, line 33, "a copper roll of wire gauze"; p. 157, line 6, "the extremely unpleasant properties of the Grignard reagent"; p. 224, line 10, "only thicker objectives demand a greater approach." On p. 7 the last paragraph on Schwarz-Bergkampff's tests of the microbalance is incomprehensible, as are also p. 105, lines 31–2, "After charging the pressure tube with silver nitrate and nitric acid, the pressure tube is pushed down the wall to the bottom of it"; p. 204, the "additivity" calculation, and p. 264, line 24, "solvents from the formula." Of mistakes may be mentioned (corrections in brackets): p. 77, line 30, p. 80, line 35, and p. 97, line 13, "c.c." (cm.); p. 97, line 12, and p. 226, line 3, "mm." (cm.); p. 195, line 4, "50 mm." (5 mm.); p. 99, line 12, "carbonate" (bicarbonate); line 33, "bicarbonate" (carbonate); p. 153, line 27, and p. 154, line 23, "decolorisation" (coloration); p. 171, line 24, "397 c.c." (0.397 c.c.); p. 179, line 17, "hydrochloric" (hydrobromic); p. 182, line 1, "iodide" (hydroxide); p. 185, line 7, "sulphate" (sulphide); p. 204, line 16, "acid" (acetone); p. 210, line 13, "chromate" (bichromate); p. 213, line 21, "thermometer" (manometer); line 27, "water" (hydrogen); p. 226, line 40, "melting-point" (boiling-point); p. 247, line 35, "compression" (comparison); p. 248, line 14, "From" (Of); p. 252, line 16, " $\pm 10^\circ \text{C.}$ " ($\pm 0.01^\circ$). There are also some obvious printer's errors such as p. 27, line 36, "Fig. 2" (Fig. 11); p. 206, equation (V) (H required on the β — C atom). The following misquoted references should read thus: p. 24, ¹B. Flaschen-

träger, *Mikrochem.*, **9**, 15 (1931); p. 41, ²A. Friedrich, *Z. angew. Chem.*, **36**, 481 (1923); p. 71, ³A. Friedrich, *Mikrochem.*, **10**, 355 (1931); p. 115, ⁴W. Münster, *Mikrochem.*, **14**, 23 (1934); p. 156, line 17, L. J. Harris ¹; p. 192, ⁵Friedrich, Rapoport, *Biochem. Z.*, **251**, 432 (1932); p. 201, J. Messinger ³ *Ber.*, **23**, 2756 (1890); p. 209, ¹C. Mayr and E. Kerschbaum; p. 223; ⁶C. Weygand and W. Grüntzig, *Mikrochem.*, **10**, 1 (1931); p. 249, line 14, R. Signer; line 15, I. K. Spies.

It is to be hoped that the publishers will exercise greater vigilance over the production of future translations of this unique handbook which is such a valuable aid to the modern research worker.

W. D.

Laboratory Methods of Organic Chemistry. By L. GATTERMANN.

Revised by H. WIELAND. Translated from the twenty-fourth German edition by W. MCCARTNEY, Ph.D., A.I.C. [Pp. xvi + 435, with 59 figures.] (London: Macmillan & Co., Ltd., 1937. 18s. net.)

WITH many chemists, Gattermann's *Praxis* will always be the favourite, and the new edition should increase their number, although the price is perhaps a little beyond that popular with most English students. The first thing that strikes one is the excellent printing, both of text and of diagrams. The latter are particularly clear, and emphasise the details which are so important. For example, an ideal "Perkin Triangle" is depicted which is so different from the ones most of us are forced to purchase.

The first 42 pages are devoted to general technique, and are very sound indeed. Then comes an account of semi-micro quantitative analysis. This is extremely well done, but it is doubtful if the Head of an ordinary University Chemical Department in this country would be able to supply his students with the necessary apparatus. It is perhaps typical that the Parr bomb method for halogens and sulphur receives no mention.

Most of the book is devoted to preparations, of which there is an excellent selection. Each experiment is most carefully described and then given brief theoretical consideration. Some of the theories given would certainly not find enthusiastic reception in some schools of organic chemistry, e.g., that the first reaction of both ethylene and benzene is addition of a molecule of the halogen to a double bond. It is perhaps satisfying to find that the author is aware that there is something to be said for the older, still not disproved, views of aromatic substitution, but the contrary to find, for example, that he regards $R \cdot N : C$ and $R \cdot N : N \cdot R'$ as the correct formulæ, respectively, for a car-

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bylamine and an azoxy-compound. Again, the melting-point of benzidine quoted is 5° too low.

These things apart, however, anyone who had acquired the knowledge and the skill corresponding to a practical digestion of the present volume would be a more than useful assistant in any chemical research work. Mention might also be made of the fact that the book gives a simple example of chromatographic analysis and a number of useful preparations of biochemical interest.

E. E. TURNER.

New Practical Chemistry. By N. H. BLACK and J. B. CONANT. [Pp. xii + 621, with 1 coloured plate and 329 figures.] (New York and London: Macmillan & Co., Ltd., 1936. 7s. 6d.)

New Laboratory Experiments in Practical Chemistry. By N. H. BLACK. [Pp. x + 193, with 1 plate and 100 figures.] (New York and London: Macmillan & Co., Ltd., 1936. 5s.)

THOSE who tread the educational mill are well aware what a long way a little kaleidoscope goes in turning a duty into a pleasure, so that "doing science" becomes instead a vivid interest in, and an intelligent enquiry concerning, the nature of things around. The authors of *New Practical Chemistry*, which is the descriptive and theoretical text-book of this pair (although it contains many suggestions for experiments), inform us that they seek to arouse the pupil's interest by appealing to his love of the dramatic and by stimulating his curiosity concerning his environment. This is a very laudable aim, and so far as the task can be performed by a text book there can be no serious complaint of the way in which it has been done. The authors would, of course, be among the first to agree that the success or failure of attempts to arouse interest, where interest is not, lies with the teacher, and that when a teacher is uninspiring even a dramatic text-book falls flat.

It is, of course, difficult to simulate drama all the time, even were it desirable to do so; in the result therefore a large part of the book has little to distinguish it from other well-written and profusely illustrated books for junior students of chemistry. The ordinary reader might complain of the triviality of many of the diagrams, although this is perhaps counterbalanced by the many pictures of chemical plant and processes; he might also wonder whether missing-word exercises are likely to appeal to students advanced enough to study the theory of electrolytic dissociation. Nevertheless, it is too easy to pick holes in an elementary text-book and to overlook the fact that freshness of presentation, even in illustration and minor detail, is well worth having, especially when the language employed is simple and direct. The subject matter includes chapters on atomic structure, on fuel, food, and clothing, on dyes and paints, and on radioactivity.

New Laboratory Experiments in Practical Chemistry, the companion volume for the bench, is (perhaps fortunately) conceived with less marked sense of the dramatic. Lest the title should mislead, it must be explained that this is not a collection of newly devised experiments, but a new manual of directions for carrying out and appreciating the significance of some ninety experiments already widely used by teachers of elementary chemistry. There are numerous diagrams, and the detail of description is adequate.

A. A. E.

Text book of Quantitative Inorganic Analysis. By I. M. KOLTHOFF, Ph.D., and E. B. SANDELL, Ph.D. [Pp. xvi + 749, with 116 figures.] (New York and London: Macmillan & Co., Ltd., 1936. 20s. net.)

VERY great strides have been made in recent years in the domain of analytical chemistry, not only in connection with the development of new methods, but also as the result of the intensive study of the errors to which the older procedures are liable. A noteworthy feature of much of this recent work has been the application of physico-chemical principles as distinct from purely empirical

investigations. Chemists are indebted to Kolthoff and his co-workers for so many contributions to this subject that one turns with expectant interest to the text-book under review, which aims at providing "a balanced outline of the theoretical and practical aspects of inorganic quantitative analysis." Technical minutiae are described with such thoroughness that selected portions of the book could be used if desired in connection with an introductory University course. The scope of the entire work is, however, that of an advanced text-book, and as such it is of exceptional merit.

The authors urge that advanced analytical chemistry is best studied after completing a course in physical chemistry. It is intended that the first 150 pages, which are devoted to the theory of gravimetric and electro-analysis, should be read at an earlier stage, and consequently no exception can be taken to the fact that the mass action law as applied to electrolytes is treated only in an elementary way. Those aspects of chemical theory, however, which are of especial importance for analysis, and which are not usually dealt with adequately in other courses, are considered very fully in the work under discussion. The chapters on the formation and properties of precipitates and on co-precipitation phenomena are especially valuable.

An outstanding feature of the book is the excellent way in which the nature of the errors involved in quantitative analysis is discussed, both in a special chapter and in the detailed discussion of all the commoner gravimetric and volumetric processes. Briefer indications are given of the utility of electro-analysis, electrometric titrations, spectrophotometry, nephelometry, and other special methods. The final section gives in fair detail procedures for the analysis of brass, steel, and silicate rocks.

This book can be highly recommended. Where other works are in use as students' text-books it would be advantageous if at least one copy could be made accessible in the laboratory.

T. B. SMITH.

Gravimetric Analysis. A Laboratory Manual, with special reference to the Analysis of Natural Minerals and Rocks. By W. VAN TONGEREN. [Pp. xii + 278, with 16 figures.] (Amsterdam: D. B. Centon's Uitgevers-Maatschappij; London: H. K. Lewis & Co., Ltd., 1937. 14s. net.)

THE main problem of rock analysis is the separation of elements very similar in chemical behaviour—a problem which can be difficult enough when only the common elements are involved. Nature is, however, no respecter of limited college syllabuses, and the frequent occurrence of small quantities of the rarer elements considerably complicates the analysis of many natural products. The book under review is concerned especially with these problems of separation, and consequently it deals in the main with gravimetric procedures. A few examples of the application of electrolytic, volumetric and colorimetric methods are also given where especially advantageous, but the more elementary, as well as the more specialised aspects of these subjects are deliberately excluded from its scope. Artificial materials which can be analysed by methods similar to those given for rocks, such as cements, slags, glasses, ashes, and alloys, are briefly considered. The estimation of the metallurgically important vanadium is not included, but those rarer elements which are widely distributed, and especially those which interfere with the estimation of the common elements, are well discussed.

This limitation of scope is an advantage in that the selected topics are dealt with authoritatively. It should be noted that diphenylamine sulphonic acid is much to be preferred as an oxidation-reduction indicator to the older diphenylamine recommended in the book. In the main, however, this work is thoroughly up to date. It will appeal both to the advanced student for whom rock analysis would provide excellent practice, and to those who are specially interested in this branch of analysis, who will appreciate for example the proposed modification of the Lawrence Smith process. In this a concentrated solution of calcium chloride is added directly to the mixture. The use of liquid permits fine grinding of the sample after weighing, and also facilitates the production of a homogeneous mixture.

The book, which is printed in Holland, is typographically pleasing, but it contains many mistakes in English. Some could easily have been corrected by any English-speaking person (such as "digerated," "spongeous," "halfs," and "f.e." instead of "e.g."); others require that the critic be also acquainted with the subject, and able to supply the correct technical terms for "containing the metal in complex binding," "additional E.M.F." (for over-voltage), "rhodanide," "cupro-sulphocyanate," "catalysator," "ammoniac," etc. None of the mistakes is sufficiently bad to render the meaning uncertain when the context is taken into account, but the use, for example, of such a phrase as "absolutely small amount" for "small absolute amount" demands at least that the sentence be read twice. It would be worth taking steps to remove such errors from any future edition, for this manual undoubtedly provides a useful addition to the literature of the subject.

T. B. SMITH.

GEOLOGY

1. **Mineralogy: An Introduction to the Study of Minerals and Crystals.** By EDWARD HENRY KRAUS, Ph.D., Sc.D., WALTER FRED HUNT, Ph.D., and LEWIS STEPHEN RAMSDALL, Ph.D. Third edition. [Pp. x + 638, with 812 figures.] (New York and London: McGraw-Hill Publishing Co., Ltd., 1936. 30s. net.)
2. **Introduction to the Study of Minerals.** By AUSTIN FLINT ROGERS, Ph.D. With a Section on Microchemical Analysis, by LLOYD W. STAPLES, Ph.D. Third edition. [Pp. xviii + 626, with frontispiece and 729 figures.] (New York and London: McGraw-Hill Publishing Co., Ltd., 1937. 30s. net.)

Two very useful and attractive text-books on the same subject, traversing essentially the same ground in the same general way. Clearly written, well printed, and profusely illustrated, these "third editions" declare the proved worth of both.

1. The merits of the first (1920) and second (1928) editions are enhanced by a general resetting of text-matter (exclusive of standardised determinative tables) and by the incorporation of recent advances in various branches of mineralogy.

This attractive volume is likely to quicken, and sustain, a beginner's interest in the science. From the outset, the student is "in touch" with realities: photographs of actual minerals, laboratory apparatus, field appliances, etc., liberally replace conventional drawings; twenty-seven

"names" eminent in the history of the science are vitalised by portraits, supplemented by brief biographical notes; contact with field, mining, and industrial practice is established by views of important mineral localities, mines, and field operations, and appropriate use is made of geographical and statistical data relating to mineral production.

The sequence of chapters is the same as that in earlier editions. An introductory review of "minerals" in relation to successive ("stone" to "metal") cultural ages of civilisation is followed by a simple and direct treatment of fundamental principles: crystallography, the physical and optical properties of minerals, and the application of X-ray work to the study of crystal-architecture (Chaps. II-XII); the manipulation of chemical data (Chap. XIII); the origins, and modes of occurrence, of minerals (Chap. XIV), and the methods of identifying them (Chap. XV). Determinative tables occupy 168 pages—tinted to distinguish them from the rest of the book. Descriptive mineralogy, and the systematic grouping of minerals, occupies Chap. XVI, and a brief chapter (XVIII) is devoted to gems and precious stones.

2. The new volume is an expansion (with considerable amendments) of earlier (1912 and 1921) editions. Perhaps its most noteworthy feature is clarity, achieved partly by typographical aids, in the presentation of the more abstruse topics comprising Part I—notably the geometry and inter-relationships of crystal forms, the optical properties of crystals, the space-lattice and the styles of crystal-architecture—leading to a concise explanation of X-ray diffraction-patterns. Discussion of chemical data includes a new and useful section on microchemical analysis.

Part II describes 222 of the more important rock-forming and economic minerals—including "mineraloids," a term applied to substances "not definite enough in chemical composition to be called minerals"; it embraces opal, limonite, pyrolusite, as well as coal and asphalt, but excludes glauconite, and leaves the status of bauxite in doubt.

Part III outlines the occurrence, association, and origins of minerals in a comprehensive way, and touches upon ore-deposits.

Part IV deals with the use of determinative tables.

Text-matter is supplemented by a bibliography of selected treatises, and a reference-list of minerals and mineraloids, with formulae.

A. BRAMMALL.

BOTANY

Methods in Plant Physiology. By WALTER E. LOOMIS, Ph.D., and CHARLES A. SHULZ, Ph.D. With a Chapter on Statistical Methods by GEORGE W. SNEDECOR, M.S. [Pp. xviii + 472, with 94 figures.] (New York and London: McGraw-Hill Publishing Co., Ltd., 1937. 25s. net.)

THIS book consists of two parts. The first part deals with laboratory exercises and contains instructions for carrying out 182 experiments covering practically the whole field of plant physiology. The second part deals with what are called "general methods." These range from the care of the desk to the estimation of carbohydrates, nitrogen and fats, and the use of the potentiometer, while chapters are also included dealing with the measurement and control of the plant environment and with statistical methods. The laboratory experiments are well selected and the description of experiments and methods clearly written. A modern practical handbook to plant physiology

and physiological methods has been badly needed for some time. For this reason this book should be found useful in all botanical laboratories where plant physiology is taken seriously.

W. S.

The Plant Diseases of Great Britain: A Bibliography. Compiled and annotated by G. C. AINSWORTH, B.Sc., Ph.D. [Pp. xii + 273.] (London: Chapman & Hall, Ltd., 1937. 15s. net.)

THIS book, the first of its kind to be produced in Great Britain, is a list of the more accessible and important papers relating to diseases of plants in this country.

Considering always the necessity to produce a volume of handy size, success has been attained, and Dr. Ainsworth well deserves the gratitude of co-workers in plant pathology—the reward mentioned by Dr. E. J. Butler, F.R.S., in his Foreword. But for those very valuable publications of the Ministry of Agriculture and Fisheries which have appeared since 1918, and *The Review of Applied Mycology*, first published in 1922, plant pathologists in this country were without any guide to the number of diseases of any one host plant, and to the original literature, and were in the position of having patiently to await the appearance of new text-books (hoping they would contain references to literature) or to make and maintain an index of their own.

Dr. Ainsworth has now provided a bibliography and in addition short notes on some of the references. An Author Index and Host and Parasite Index are included. The Preface makes it clear that not all the published work on every disease could possibly be listed and therefore original papers and other key references are principally dealt with. For this the very good reasons are given that the size of the book has to be considered as well as the ease of keeping it up to date; it is well that the author has thought of revisions for these will almost certainly be necessary. By quoting only key references, some alterations and additions may be avoided, but with the constant occurrence of new diseases and new hosts for old diseases, changes are inevitable. Some provision might have been made by means of spaces or blank pages for the reader to add further references if the book is to do away with the necessity for keeping a card index.

A small criticism is that the title might perhaps have indicated that diseases of cultivated plants are mainly considered. Spelling mistakes of generic and specific names are frequent in the text and these are commonly repeated in the Index, but it is surprising to find generic names (e.g. *Pachybasium*, *Ornithogalum*, *Phyllachora*) spelled correctly in the text and incorrectly in the Index. Even an English name such as "Hawthorn" is misspelled both in text and Index and one is forced to the conclusion that more care should have been taken in reading the proofs.

Adequately to review a Bibliography such as this, dealing with a multitude of diseases caused by fungi, bacteria and viruses, would require the services of a committee of specialists and, moreover, those specialists should be very familiar with the host plants listed, for they range from mushrooms to trees. In the opinion of the present reviewer, it seems complete, concise and accurate in quotation of references. It is a well printed, well arranged and most useful book.

W. M. WARE.

Grass Drying. By S. W. CHEVELEY, M.Sc. With a Foreword by SIR DANIEL HALL, K.C.B., F.R.S. [Pp. 127, with 9 plates.] (London: Ivor Nicholson & Watson, Ltd., 1937. 6s. net.)

DURING recent years the drying of grass has become a fashionable topic of discussion among a certain section of the progressive agricultural community, for it is so seldom that what is really a revolutionary procedure can be applied to a produce that is so familiar to the farmer and of which his production beyond immediate requirements has been taken care of by the age-long process of haymaking. It was Woodman at Cambridge soon after the war who first pointed out that grass contained most protein and therefore nourishment when the blades were two to three weeks old, and that if cut at this stage it was one of the finest possible agricultural foods. Later, when the blades were one to two months old, and approaching the haymaking stage, the protein content was relatively much less, and decreased further during the actual haymaking process itself. Woodman therefore suggested cutting the grass when it was young and artificially drying to convert it into a stable, highly nutritious food—now known to be the equal of oil cake—for storage as winter ration.

On these simple postulates the new industry of grass drying has been slowly built up, and all has not been by any means plain sailing. The fact that nitrogenous fertilisers would increase two- or three-fold the yield of young grass was an incentive to the fertiliser industry and money was soon available for research. But drying is not easy, for in practice it means the conversion of 70 per cent. of the weight of the grass into steam, and this requires much heat. The first machines for the purpose were unwieldy and terrifying not only to the farmer's sight but to his pocket as well! Progress has therefore been slow, but all the same the advances made have been very real, and we shall be in a position to judge during the next few years the effect of soil and season on the protein yields of the finished product, for the cost of a unit of protein in dried grass compared with that in an oil cake is the overriding economic factor on which the new industry will flourish or fall.

Mr. Cheveley has been actively engaged in this new field since the inception of grass drying on a commercial scale and he has produced a well-balanced and very readable book which will be indispensable to those, and they are a growing band, who see in the new industry a partial salvation for British agriculture.

A. C. C.

Oils from Irish-grown Plants. Preliminary Report by Prof. JOSEPH REILLY, M.A., D.Sc., F.R.C.Sci.I., and DENIS F. KELLY, M.Sc. *Agricultural Bulletin* No. 4. [Pp. 92, with 6 plates.] (Cork University Press; London: Longmans Green & Co., Ltd., 1937. 2s. 6d. net.)

THIS report gives an account of an investigation undertaken to ascertain the possibility of growing certain oil-producing crops in the Irish Free State. A case is made out for the growing of linseed and rape for the oils which they yield, and preliminary field experiments would appear to justify large-scale cultivation tests of poppy seed. It is asserted that the work is entirely of a preliminary nature dealing mainly with the chemical and technical rather than with the economic aspect. Results of field trials for hemp and sunflower are not conclusive though there is evidence that these crops can be successfully cultivated. Other plants which have been experimented with are hemp,

mustard, soya bean and *Mercurialis annua*. The report contains statistical data on oil production in various countries and also analytical data concerning the various oils, and in an appendix a brief account is given of experimental methods employed.

P. H.

Vergleichende Morphologie der höheren Pflanzen. I. Band: Vegetationsorgane, 1. Teil, 2. Lieferung. Von DR. WILHELM TROLL. [Pp. 173-508, with 286 figures.] (Berlin: Gebrüder Borntraeger, 1937. RM. 27.-; subscription price RM. 21.60.)

THIS continuation of Dr. Troll's work on the morphology of the "Vascular" plants is concerned, like the first part, with the vegetative organs. The present sections treat of the differentiation of the shoot into nodes and internodes; the periodic development of the internodes and their influence upon growth form; the growth of the leaves at the meristem and theories respecting the relation of leaf and shoot; leafless shoots; the symmetry of the shoot and leaf; the habit and growth forms of the Pteridophyta, etc.

Like the part already reviewed, the text is very fully illustrated with photographic reproductions and clear explanatory diagrams, and is an earnest of the full treatment which morphology will receive when the work is completed.

E. J. S.

PEDOLOGY

Soil Erosion and its Control. By Q. C. AYRES, C.E. McGraw-Hill Publications in Agricultural Engineering. [Pp. xii + 365, with 244 figures.] (New York and London: McGraw-Hill Publishing Co., Ltd., 1936. 21s. net.)

THE idea of the World as relatively static is held by a considerable proportion of even educated persons, and so when dynamic aspects are forced upon our notice the phenomenon is frequently regarded as abnormal, whereas it is the magnitude of the phenomenon, and not the phenomenon itself, which is unusual. As the author of this book wisely remarks, "What takes nature hundreds or even thousands of years to manufacture, Man can and often does destroy almost overnight by haphazard land use and improvident husbandry."

The problem of erosion in the United States has been forced into prominence not by its novelty but by the sudden and overwhelming scale of its consequences, due to a combination of the effects of prolonged and thoughtless exploitation by man and a succession of exceptionally dry seasons.

The terrible toll of between thirty-five and fifty million acres of cultivated land totally ruined and abandoned, with the partial or complete removal of the top soil from a further area of one hundred million acres, is a disaster so vast as to be difficult, if not impossible, to grasp—an area of some 230,000 square miles more or less ruined, or nearly twice that of the whole land area of Great Britain and Ireland.

Qualitative comparisons of the holding power of various types of vegetation appear to show that their diverse capacities to retain soil are in direct proportion to the degree of their natural adaptation to environmental conditions. Hazel-Bush and Oak-Hickory would, according to the author, appear to be most efficient, both with respect to water retention and the prevention of erosion.

The author is an agricultural engineer, and as such it is natural that the more constructional aspects of control—the making of dams, the design,

location and construction of terraces, their costs and maintenance, the terrace outlets and the control of gullies, to each of which a chapter is devoted—should all receive full consideration. Whilst due recognition is accorded to the valuable and indeed indispensable rôle of vegetation, to which in fact the constructional works are really subsidiary, one would have welcomed a fuller account of the biological factors than is here furnished. The effects of forests on stream flow and erosion, which have been extensively studied by French foresters, here receive rather meagre treatment.

Though not as comprehensive as the title might lead one to suppose, this volume is a useful handbook to the problems facing those engaged in combating the forces of erosion.

E. J. SALISBURY.

Engineering Properties of Soil. By C. A. HOGENTGLER, C.E. [Pp. xiv + 434, with 198 figures.] (New York and London: McGraw-Hill Publishing Co., Ltd., 1937. 30s. net.)

In this volume the author has made a meritorious attempt to co-ordinate the purely scientific aspect of soil mechanics with some of the difficulties which confront the practising engineer. It is probable that a considerable time must still elapse before the numerous theoretical investigations into this subject can be crystallised to an extent which would enable the Properties of Soil to be classified as Engineering rather than Chemical, Physical or Mathematical.

The first three sections of the book deal largely with the latter, while the last section is devoted to Practical Design and Construction. The word "practical" used in conjunction with Engineering Design as affected by Soil Properties raises the hope that the methods of analysis given might be expected to yield definite results. This hope is perhaps justified by references to particular problems rather than to general engineering practice. Differentiation between Theoretical and Actual Engineering Design sometimes leads to confusion between the Pure Sciences and empirical rules of thumb. The author has achieved considerable success when attempting to negotiate this passage between Scylla and Charybdis as well as in maintaining a partial balance between the devilment of some colloidal theories on the one hand and the deep sea of empiricism on the other.

The book is well illustrated and the diagrams and tables are set out in the workmanlike manner usually found in American publications. The comprehensive bibliography should be of assistance to the student of Soil Mechanics, though the field is somewhat specialised when comparison is made with the *Proceedings of the International Conference on Soil Mechanics and Foundation Engineering* held in June 1936.

The author by his work has contributed to one of the most controversial and yet one of the most important branches of Engineering Science.

H. J. COLLINS.

BIOLOGY

Evolution. By A. FRANKLIN SHULL. [Pp. x + 312, with 64 figures.] McGraw-Hill Publications in the Zoological Sciences. (New York and London: McGraw-Hill Publishing Co., Ltd., 1936. 18s. net.)

In this book Prof. Shull has endeavoured primarily to give an account of evolution in the light of modern genetic work. Such an attempt is deserving

of high praise, and this survey is undoubtedly valuable. There is much in it which will stimulate the interest and curiosity of the student. There are certain sections, however, which may stimulate also his criticism, for the manner of presentation, and the interpretations here adopted, are not always unexceptionable. As the work will no doubt be widely studied, it may be useful to draw attention to a selection of such points, in order that readers may be alive to the necessity of analysing for themselves the facts here discussed.

In general, the book is somewhat loosely written. Facts are often quoted without references: indeed, the whole might be much more thoroughly documented. The scientific names of the species mentioned are frequently omitted (pp. 170, 188, and many other examples). Furthermore, the writing is rather inexact. This is a great misfortune where any genetic subject is being discussed, as extremely clear wording is then an essential. Such phrases as "triangular and spindle-shaped genes" (p. 113)—in relation to genes producing triangular and spindle-shaped capsules—should of course be most carefully avoided. The term "mutation" must be restricted to the inception of an heritable variation, and should never be used for the altered gene to which a past mutation has given rise, as is done here (e.g. p. 150).

In a few instances, well-known biological facts are incorrectly explained. Thus, it is not in accord with modern discoveries in cytology to state that no trace of gene multiplication can be seen till early in mitosis (p. 72). It is of course now known that the chromosomes are already split longitudinally into chromatids when mitosis begins. On p. 138 we are told that the members of a pair of allelomorphs are in stable equilibrium when the three possible genotypes AA , Aa , aa are in the ratio $p^2 : pq : q^2$. The author goes on to remark that "anyone who does not trust the algebraic calculation necessary to arrive at this conclusion can readily substitute for p and q any specific values—and demonstrate that with random combination they should retain these values generation after generation." It is to be hoped that the majority of Prof. Shull's readers will be sufficiently sceptical to undertake this task, and that they will then discover for themselves that in reality equilibrium is reached when the proportion of heterozygotes is twice the square root of the product of the frequencies of the two homozygous classes.

Prof. Shull attempts to lay too great a burden upon the direction of mutation, nor does he quote Fisher's demonstration that, in a system of particulate inheritance, agents affecting mutation are very inefficient for controlling evolution. The argument on pp. 123-6 is not worth developing. Surely no one is likely to suppose that every gene is capable of mutation in all directions. By the random nature of mutation it is implied that an agent causing mutation is no more likely to evoke one than another of the changes possible for a given gene.

Parallel mutation is involved in one of Prof. Shull's least successful arguments, that on mimicry. This appears to be a subject which he has not studied very deeply. He has evidently not realised the complete superficiality of most of the resemblances involved in this phenomenon, which excludes the possibility that they can be due to the same genes. He even argues in a circle to the extent of suggesting that purely superficial resemblances may be due to parallel mutation, because genes may have different effects in different gene complexes (p. 185). When the genes cannot be proved identical, and the effects they produce are not the same, the grounds for assuming that they are due to parallel mutations seem poor. Prof.

Shull does not seem to have appreciated the wide range of forms, often exhibiting only most distant relationships, affected by mimicry, nor that it frequently necessitates resemblances, not only in colour and pattern, but also in shape and habit. However, it is no doubt unfair to judge a book by one of its less satisfactory components.

In his discussion on natural selection, Prof. Shull tends to under-rate the variability of the response of organisms to environmental changes, and consequently their susceptibility to selection (p. 152). The ease with which it is possible to alter by selection the resistance of organisms to such changes, and their response to them, should have been pointed out.

Prof. Shull comments on the small amount of evidence which demonstrates the effect of natural selection (p. 211). Had he given us a summary of some of the more striking modern work on this subject, the deficit would be much less apparent. The results of Gordon and of Timoféeff-Ressovsky, among others, should certainly find a place here.

There is, however, much to commend in this book. In particular, the very proper caution may be mentioned with which the author interprets the results of McDougall's experiments upon the inheritance of learning in rats.

E. B. F.

Nematodes Parasitic in Animals. By GEOFFREY LAPAGE, M.A., M.D. Methuen's Monographs on Biological Subjects. [Pp. x + 172.] (London: Methuen & Co., Ltd., 1937. 4s. 6d. net.)

DR. LAPAGE has managed to pack into this small book an astonishing amount of information especially on the physiology of the nematode parasites of animals. The work consists of four chapters. The first, pp. 1-27, covers structure, life-histories and classification; the second, pp. 28-95, deals with physiology under five heads; the third, pp. 96-130, treats of the resistance of the host to nematode infestations under seven heads; whilst the last, pp. 131-137, deals briefly with the control of nematode infestations. There is a list of 404 references and a good index.

Where the treatment of the subject-matter comprising the greater part of the book is so good, it seems a pity that a number of errors should have been allowed to pass unremedied. No doubt in a work of this kind it is inevitable that great compression must be attempted, but the sense of overcrowding and of telescoped statements is very noticeable in the first chapter where the following have been noted. On p. 19 it is stated that the larvæ of *Strongyloides* and *Dracunculus* pass out with the fæces. On the same page, in discussing the life-history of *Strongyloides*, one finds the statement that the eggs laid by the sexual, free-living generation give rise to *filariform* larvæ; the fact that these develop from *rhabditiform* larvæ being omitted. On p. 21 it is erroneously stated that the larvæ of *Dictyocaulus filaria*, parasitic in the lungs of sheep, develop in species of *Lumbricus* and *Eisenia*, whereas the life-history is direct. The book could scarcely be recommended to anyone not already equipped with a fair knowledge of nematodes as a group, especially as there is an entire absence of drawings, but to a worker interested in problems of physiology, metabolism and host-parasite relationships it can be cordially recommended as providing a compact discussion of most of the recent literature on these matters.

T. G.

Recent Advances in Cytology. By C. D. DARLINGTON, D.Sc., Ph.D.
Second edition. With a Foreword by J. B. S. HALDANE, M.A., F.R.S.
[Pp. xvi + 671, with 16 plates and 160 figures.] (London: J. & A. Churchill, Ltd., 1937. 21s. net.)

THE title of this book is rather misleading, as it is devoted primarily to the cytology of the nucleus in relation to genetics. The vast amount of work, which has been carried out in this field within recent times, has been critically reviewed by the author. The opening chapters are devoted to a description of the structure and behaviour of chromosomes during mitosis, and an account of meiosis in diploids and polyploids. Succeeding chapters are devoted to structural hybrids and polyploidy. A discussion of the chromosomes in heredity is concerned mainly with showing the parallelism between "the rules of heredity and the rules of chromosome behaviour." The author defines the gene as "the unit of crossing-over, and therefore the atom of inheritance." The remaining chapters are devoted to permanent hybrids, the breakdown of the genetic system, and cell mechanics.

Full use has been made of diagrams to clarify the text, and to illustrate theoretical interpretations of chromosome behaviour. A great amount of work has been summarised in the form of tables, which are specially useful for purpose of reference. The new terms, which have been introduced in this branch of cytology, and in genetics, of recent years, make the glossary of special value to those who are not specialists in these branches of biology.

In the Foreword, Prof. J. B. S. Haldane points out that "for some centuries the deductive method in the biological sciences has been very properly suspect. But first in genetics, and now in cytology, we have returned to it," for as Dr. Darlington explains, "it is possible to base prediction of chromosome form and behaviour on observations by genetical methods, and *vice versa*, and these predictions can afterwards be tested."

This book provides an excellent survey of one of the most progressive branches of modern biological research.

R. J. L.

Biological Laboratory Technique: An Introduction to Research in Embryology, Cytology and Histology. By J. BRONTH GATENBY, D.Phil., M.A., Ph.D., D.Sc. [Pp. vii + 130, with 8 figures.] (London: J. & A. Churchill, Ltd., 1937. 7s. 6d. net.)

THIS book is intended to furnish the University teacher or student, and the amateur, with a short and simple introduction to modern microtomy. The treatment is thoroughly practical and concise. The author deals with the examination of living cells and the preparation of smears, whole mounts and sections; the latest methods of fixation, embedding and staining receive attention, and a chapter is devoted to microchemical tests. There is also a brief account of the Beam's ultra-centrifuge. Zoological methods are dealt with primarily, although occasionally botanical techniques are mentioned.

Two noteworthy features are, critical summaries of the merits and demerits of the methods described, and an attempt to indicate the pitfalls and causes of failure in the various methods.

An error in proof reading appears on p. 77, where Champy's fluid is described as a mixture of potassium bichromate, *oemic acid* and osmium tetroxide.

Among the rather numerous books on microtomy the present volume

should rank high. It may perhaps be best likened to an up-to-date, abridged edition of the *Microtomists Vade Mecum*, by one of the editors of the three last editions of this standard work, and for such a book biologists generally will have cause to be grateful to Prof. Gatenby.

F. W. J.

The Biological Control of an Insect in Fiji: An Account of the Coconut Leaf-mining Beetle and its Parasite Complex.

By T. H. C. TAYLOR, M.Sc. [Pp. x + 229, with 2 maps, 23 plates and 17 figures.] (London: The Imperial Institute of Entomology, 1937. 12s. net.)

ALREADY two accounts have been published of biological control campaigns in Fiji. The first, *The Coconut Moth in Fiji*, previously reviewed (see SCIENCE PROGRESS, XXV, No. 99, 1931, 542-3), described the successful control of this moth by a Tachinid parasite *Ptychomyia remota*. The second was a paper describing the control of the scale insect *Aspidiotus destructor* by a predatory Coccinellid beetle *Cryptognatha nodiceps* (Bull. Ent. Res., 1935, 26, 1-102). In each of these instances the control has proved permanent.

The present book deals with the campaign to find a biological control of the leaf-mining beetle *Promecotheca reichei*. This pest was indigenous in Fiji together with its primary and secondary parasites. These maintained a perfectly satisfactory control until recent years when a foreign mite, *Pediculoides ventricosus*, arrived and upset the balance. This mite has periodically eliminated all but one of the developmental stages of the beetle, creating what Mr. Taylor terms the "one-stage" condition. In simple words the "one-stage" condition is one in which successive generations cannot appreciably overlap each other. This is a normal occurrence in temperate countries where the factors causing this condition are largely seasonal climatic changes. On the other hand, the "multiple stage," in which all stages occur simultaneously, usually obtains in the tropics. As a consequence of the leaf-mining beetle being in the "one-stage" condition the indigenous parasites were unable to deal with the situation and the beetle became a pest.

The problem was thus to find something which was able to satisfy unusually rigid requirements. It was also a case of controlling an insect in its native environment.

The book is arranged in an orderly manner starting, after a short introduction, with a full account of the leaf-mining beetle. Then follows a chapter dealing with the parasites and predators associated with it in Fiji prior to 1933. The next chapter describes the beetle as a pest and discusses its outbreaks and this is followed by an account of the nature and extent of the control exerted by the parasites and other factors before 1933. Having thus set the stage, so to speak, Mr. Taylor describes the search for the special type of parasite required. Its desired character is carefully worked out on theoretical grounds. Several parasites were found but finally *Pleurotropis parvulus*, a Eulophid, was chosen. This insect is a primary internal parasite of all stages of the larvæ and pupæ of *Promecotheca nucifera* and *Gonophora xanthomelana* in Java. Chapter 7 describes this insect in detail from almost every aspect. The next chapter narrates the introduction of this parasite and two others from Java into Fiji and the penultimate chapter

gives the methods employed in breeding and studying the beetle and its parasites and for collecting data in the field. The last chapter consists of twenty-eight references. Finally come the twenty-three plates.

It would be difficult to find a more complete account of a successful entomological campaign in book form. The arrangement is such that if one wishes one can follow the project from beginning to end without being hampered with details. A re-reading provides the details. Some of the wider and more fundamental aspects of biological control are revealed in the course of working on the case under investigation. The book is easy to handle and pleasant to read, while the price, thanks to special grants, is low.

H. F. B.

The Locust Outbreak in Africa and Western Asia in 1935. By B. P. UVAROV, D.Sc., and Miss W. MILNTHORPE, B.Sc. [Pp. 63, with 9 maps.] (London: H.M. Stationery Office, 1937. 3s. net.)

THIS is the fifth report of the Committee on Locust Control and covers a period in which the destructive outbreak of the last eleven years has been subsiding. It is rightly stressed that the intermission of immediate danger is no excuse for a slackening in the study of the species, which can only be controlled by maintaining them at their present or at a lower level. There is one especially valuable type of observation that can be made only when locust numbers are at the minimum, viz. to determine the permanent breeding areas. During an actual outbreak breeding may take place over a very wide area, but as the outbreak recedes breeding becomes more and more restricted, till finally it goes on only in a few rather well-defined localities, which will be the source of the next outbreak. In the African Migratory Locust it is already highly probable that the only permanent danger spot is the Middle Niger region, and a plan for continuous supervision of this area is already in being. With the Desert Locust and the Red Locust which have more scattered breeding centres, the position is not so clear cut and, in the Red Locust especially, there may be more permanent breeding-places than those known at present. The Red Locust, too, has been found to cross the equator in Eastern Kenya and to invade Somaliland. It was thought previously that climatic conditions would prevent this; fortunately the swarms were unable to breed in Somaliland and died there without laying eggs. The Imperial Institute of Entomology and Dr. B. P. Uvarov are to be congratulated on a series of reports not only of great economic importance but also of the highest scientific interest, giving us a picture of a way of living and maintaining numbers very different from that of the ordinary insects of the temperate zones.

O. W. R.

A Preliminary Investigation into the Causes of Scale Absorption in Salmon (*Salmo salar*, Linné). By VERNON D. VAN SOMEREN, B.Sc. Fisheries Scotland, Salmon Fish., 1937, No. II. [Pp. 12, with 1 figure.] (Edinburgh: H.M. Stationery Office, 1937. 9d. net.)

WORK on this subject has already been carried out in the interests of the Fishery Board for Scotland by M. I. Crichton, the results being published two years ago. From the similar biochemical research of Prof. Neave of Manitoba, it appears that the subject has to be regarded as one which requires

further attention, but Rauther in Germany having ascertained the chemistry of scale material in teleosts, the method of approach followed in the present author's work has been determined. It has been found that 30 to 40 per cent. of the scale material is inorganic and chiefly calcium phosphate, and the attempt has been made by calculating the serum calcium values to ascertain the conditions of absorption.

Blood samples were taken from newly killed salmon at the mouth of the Tay, half-way up the Tweed and in the tributary of the Ettrick, and it has been found that a striking seasonal variation appears in the female salmon as spawning time is approached, while the values in males remains constant till just before spawning. In females it rises from 18 to 19 per cent. to 44.2 mg. per cent. when the fish is ripe for spawning. In the males it remains about 15.5 mg. to 16 mg. per cent., and at spawning-time drops to 11.1 or so. A graph shows the difference very clearly, but since it is the case that males show much more absorption in their scales than females, this line of approach to a solution of the problem seems to have failed. At the same time it is clear that there is some connection between the serum calcium value and the state of the gonads.

We think the reasoning is sound which takes note of the connection between the periods of feeding and non-feeding and the metabolism of calcium. Green's work in America is quoted in this connection, while the extensive work of Noel Paton and his colleagues, published by the Fishery Board for Scotland about 40 years ago, appears to be overlooked. The scales may be a natural store of the minerals necessary for the upkeep of the fasting fish, yet this does not supply us with any account of the process of absorption. Dr. Foerster, Canada, has suggested that the development of the secondary sexual characteristics such as the hook on the jaw or "kype" of males—and we might add the marked thickening of the epidermis—may be an explanation of the calcium absorption in males, or the difference between the sexes, but this has not, so far, been followed up.

Although a rather negative result emerges from Mr. van Someren's Preliminary Investigation, his paper is a most suggestive one.

W. L. C.

Mytilus. By KATHLEEN M. WHITE, B.Sc. L.M.B.C. Memoir No. XXXI. [Pp. viii + 117, with 10 plates.] (Liverpool: The University Press of Liverpool, 1937. 9s. net.)

AN addition to the valuable series of the Liverpool Marine Biology Committee's Memoirs on Typical Marine plants and animals has been made by Miss Kathleen M. White with her memoir on *Mytilus edulis*, the common mussel of our shores. The mussel, which is a Lamellibranch mollusc belonging to the order Filibranchia, is an animal of considerable food value, whose culture flourishes more on the continent than in the British Isles. Fear of poisoning is probably largely responsible for the lack of popularity of this shellfish, since they are ciliary feeders and very liable to sewage contamination. The beds are close inshore and thus often in the neighbourhood of sewage outfalls. It is however now possible always to obtain mussels of certified purity since the introduction of the system of cleansing tanks by the Ministry of Agriculture and Fisheries, which were first proved out at Conway.

The main part of Miss White's memoir is on the external characters and anatomy of the mollusc, but it is prefaced with an interesting account of the

biology of the species and its economic importance. Throughout the descriptive part also mention is made of experimental work elucidating the functions of the various organs. The work ends with a section on the life history and development and a most useful literature list of 196 references. As *Mytilus* may be regarded as one of our commonest bivalves the memoir should prove very useful not only to students but to all interested in natural history and the structure of animals.

F. S. R.

HISTORY OF SCIENCE AND PHILOSOPHY

Origins of Clerk Maxwell's Electric Ideas as described in familiar letters to William Thomson. Edited by SIR JOSEPH LARMOR. [Pp. vi + 56.] (Cambridge: at the University Press, 1937. 3s. 6d. net.)

THIS volume consists of a series of informal letters written by James Clerk Maxwell to William Thomson during the period 1854 to 1879. The letters have been selected, arranged and to some extent annotated by Sir Joseph Larmor, who also contributes a foreword. The letters were originally issued as Part V of Volume 32 of the *Proceedings of the Cambridge Philosophical Society*, but as they are clearly of much interest to a wider circle a more general form of publication is welcome.

In the earlier letters Maxwell is asking Thomson for information about electrical matters, a subject which, together with his theory of colour, occupied his attention after having "entered the unholy state of bachelorhood." "Suppose a man to have a popular knowledge of electrical show experiments and a little antipathy to Murphy's Electricity, how ought he to proceed in reading and working so as to get a little insight into the subject which may be of use in further reading?" This was in a letter addressed from Trinity College in February, 1854. At the end of the same year there is a statement of "the confessions of an electrical freshman," a summary of the clearer ideas which had emerged in the course of his reading. As the letters proceed we realise how he groped towards his structural theory of the interrelated law of electric and magnetic force. From his house in Kensington, when he was Professor of Natural Philosophy at King's College, London, he writes (1861): "I suppose that the 'magnetic medium' is divided into small portions or cells, the divisions or cell-walls being composed of a single stratum of spherical particles, these particles being 'electricity.' . . . By comparison with Weber's value of the statical measure of a unit of electrical current I have deduced the relation between the elasticity and density of the cells. The velocity of transverse undulations follows from this directly and is equal to 193,088 miles per second, very nearly that of light" We can readily understand why the same letter contained the question: "Do you know any good measures of dielectric capacity of transparent substances?"

The letters show us the youthful eager Maxwell better than any biography can do. Sir Joseph Larmor is the most unobtrusive of editors and is mainly content to let them tell their own story. But one hint he gives us should surely be followed. While perusing this volume we should take down from our shelves the Clerk Maxwell *Commemoration Volume* (Cambridge University Press, 1931) and look again at that delightful beardless photograph of Maxwell as a young graduate, the young man who wrote the earlier of these letters.

E. V. A.

The Drama of Chemistry. By SIDNEY J. FRENCH, Ph.D. [Pp. viii + 170, with frontispiece and 112 figures.] (New York: The University Society; London: Chapman & Hall, Ltd. 1937. 4s. 6d. net.)

THIS is the volume on chemistry in "The University Series: Highlights of Modern Knowledge," a collection of works intended "to present, in an attractive form and in a concise, readable style, the truly amazing story of the life of mankind—an authoritative survey of the physical and social sciences, history, philosophy, literature and the arts." The composite illustration on the dust-wrapper is well in keeping with the object of the series, but, since chemistry may well be the oldest science and is unquestionably the one that touches life at all points, it is curious that this science finds no place even in a remote corner of the wrapper. As for the book itself, it is a popular work for the general reader; the form is attractive and the style readable; and it is a feat to have compressed so much into so small a space. But in places there is a lack of perspective, not necessarily due to compression, as in the phrase "the black magic of alchemy" and the statement: "Originally little more than a hobby in which statesmen, clergymen and others dabbled, chemistry has now become a profession." And surely it is surprising that in an American book Priestley's name should appear as "Priestly"; while, compared with the statement that the doyen of British chemistry, Armstrong, was born in 1876, the dating of the battle of Crécy as 1490 is a minor historical slip.

D. McKie.

The Philosophy of Relativity. By A. P. USHENKO, Ph.D. [Pp. 208, with 11 figures.] (London: George Allen & Unwin, Ltd., 1937. 8s. 6d. net.)

THE author tells us that he proposes to construct a philosophy which shall be a possible interpretation of the formulæ of Relativity. It is therefore legitimate to point out that few physicists would agree with the author's version of the theory of Relativity given in Chapters II, III, IV and VI. Fundamentally this presupposes that flat Euclidean space is in some sense "true": thus, on page 67, there is mentioned the "witnessing of intuition that space is Euclidean." But Relativity is credible and useful to the physicist only because he has found that there is no such a priori method for deciding whether space is flat or curved. This predisposition in favour of flat space leads the author to apply the formulæ of special relativity to physical situations whose possibility is ruled out by the axioms of the theory. An instance occurs in the problem of the relative "ageing" of two twins, one of whom stays on earth whilst the other travels to a distant star and back. Since the motion of the second twin is necessarily accelerated for some part of the time, the formulæ of special relativity, which assume constant relative velocity, do not apply to his journey. Again the author apparently believes that in general relativity an observer cannot make world-wide separations of space from time (page 108). The observer cannot, of course, do this in terms of plane sections of space-time as is possible in special relativity. The use of plane sections is however quite irrelevant: in general relativity space and time can be unambiguously separated by means of curved sections. Indeed, the whole theory of the expanding universe is based on this possibility. Finally the many misprints in the mathematical sections of the book might make the latter difficult to follow for anyone not already familiar with their subject-matter.

In the metaphysical portion of the book, Dr. Ushenko replaces the category of physical substance by that of events regarded as agent-acts. He concludes that space-time is real and is not merely a conceptual framework convenient for the ordering of a certain class of observations. The fact that quantum phenomena have largely escaped inclusion in the continuous space-time scheme of relativity is not touched upon in reaching this conclusion.

G. C. McV.

MISCELLANEOUS

What Science Stands For. By various Authors. [Pp. 132.] (London : George Allen & Unwin, Ltd., 1937. 5s. net.)

THIS book is a series of essays by six authors, presenting various aspects of the impact of science on human affairs. Thus in the first essay Sir John Boyd Orr treats of the new orientation regarding standards of nutrition, necessitated by the realisation that food is not merely a question of calories, but that full health is only to be attained by the supply of a certain minimum of an increasingly wide range of vitamins, involving a much extended dietary. The second essay by Prof. A. V. Hill emphasises in a very delightful manner the essentially international character of the scientific spirit, under the title of "The Humanity of Science." Prof. Philip stresses the part played by the chemist in the service of the community and considers the curriculum that the potential chemist should pursue. Sir Richard Gregory emphasises the cultural value of science, whilst Sir Daniel Hall writes of the increase of power that knowledge gives, of its advantages and potential dangers. In the last essay Prof. Hogben gives his views on science in education.

Although most suited for the general reader, several of the essays will be read with interest by the professional scientist.

E. J. S.

Darwin's Theory Applied to Mankind. By ALFRED MACHIN. With a Foreword by SIR ARTHUR KEITH, F.R.S. [Pp. xxiv + 284.] (London, New York, Toronto : Longmans, Green & Co., 1937. 7s. 6d. net.)

It is in no sense an adverse criticism to say that Mr. Machin's book is provocative. To discuss it adequately would require a commentary as long as the text. The whole history of man, as man, it is argued, falls into a series of four stages, beginning with the solitary hunter, and passing through the social hunting stage and the slave stage to the free stage. In these stages two codes of morality emerge. The earlier has for its end the promotion of qualities and characters which tend to the preservation of the group, internally by regulating the relations of its individual members and externally by securing its survival among other competing groups. The second and later code is that in which the aim is to promote the creation and acquisition of wealth. Man as he exists to-day is a bundle of survival values, which have been inherited by natural selection from among the characters which once conduced to survival in each of the four stages. Other characters, such as those called man's natural instincts, have been, or are, suppressed. Those which have survived are manifested in work, fruitful marriage, and patriotism. As regards the future, Mr. Machin holds—and given certain reservations, his contention can hardly be disputed—brain power will be the next great positive survival factor.

As Sir Arthur Keith points out in his foreword, Mr. Machin is whole-

heartedly an "evolution is" man. That is to say, he does not hold with many that evolution as applied to man is operative only in a biological sense, as determining his physical development. He regards it as at work throughout the whole story of civilisation; while the future is being shaped by a process of natural selection in which that type survives which is best able to avail itself of the advantages of man's advance in the control of environment which constitute progress. Mr. Machin's emphasis on wealth as the end of his later moral code makes his doctrine seem at first sight a little crude; but post-War development makes it difficult to refute. Unless the dominance of brain power makes a reconstruction of the forms of society a necessity, the struggle for existence both as between groups and individuals seems likely to become more bitter.

E. N. F.

Environment and Nation. By GRIFFITH TAYLOR, D.Sc. [Pp. 571, with frontispiece and 147 figures.] (Toronto: The University of Toronto Press; London: Humphrey Milford, 1936. 17s. net.)

THE progress of a science is secured in more than one way. In the first place it proceeds, indeed must proceed, by the careful amassing of facts—the collection of material of which the future edifice is to be built. But just as a builder and architect may produce from the same material a temporary structure, a solid but uninspiring edifice or a daring experiment, so the facts of such a science as geography may be arranged to give very different results. Prof. Griffith Taylor, the author of the book under review, has served his apprenticeship as a maker of bricks—his detailed researches into meteorology and geography in Australia, into the palæontology and geology of Antarctica and Australia are too well known to need comment. But he occupies now a unique position as a brilliant exponent of broad principles and illuminating theories. As a champion of what he believes to be the truth Prof. Taylor is fearless. A dozen years ago, as Professor of Geography in the University of Sydney, he was wont to emphasise the extreme difficulties imposed by climate in the development of tropical Australia and the dry heart of the continent. Fighting against the tide of optimism of the moment he became one of the most unpopular figures in Australia; to-day most of his assertions have been shown to be well founded. In the book *Environment and Race* to which the present work is the second in a proposed trilogy he introduced amongst many other ideas the geological concept of inlier and outlier into the field of anthropology. He now turns his attention to the cultural geography of Europe and claims that his book is a protest against narrowing the fields of science unduly. The field which he takes is to a large extent "unclaimed by the geographer, geologist, historian, ethnologist or sociologist, and yet owing much to all these disciplines." The resulting geographical interpretation of European history is an objective treatment which depends for its success on a nice selection of salient facts and a sound judgment in the formulation of generalisations. No one can read the book without a sense of profound admiration for the author's handling of an immense variety of facts or for his remarkable facility for their presentation in new and ingenious maps and diagrams. Many of the diagrams (e.g., Figs. 30 and 31 as well as Fig. 1) are masterpieces of skill in compression.

Such a book must inevitably evoke criticism from specialists in the varied fields upon which it touches. But it cannot be denied that it is immensely

stimulating and some of the diagrams and statements most open to criticism are those which no other author has dared attempt—by reason of the very difficulty of the subject matter involved. If, however, there is a general criticism it is of the number of statements which are not *strictly* accurate. It may often be urged that the argument involved is not affected but, if deliberate, the expedient seems unwise. Thus, on p. 220 the statement that London "occupies the centre of the youngest beds of the Tertiary Basin where the sea has scoured out a broad estuary in the soft rocks" is not *strictly* accurate though the general argument is not affected. Similarly on p. 281 "it is not far from the truth to say that in the lowlands between Luxemburg and Amsterdam we see a sequence of rocks much like that discussed earlier as extending from London to Snowdon" is actually sufficiently far from the truth to be misleading.

Similarly some of the diagrams are illuminating, others are less successful, a few definitely misleading. An example of generalisation which has seriously overlooked salient principles is found in Fig. 3—a diagram which further defeats its own ends by obscuring the main features it should emphasise.

This is a book with many faults, but with such an abundance of ideas as to make it of real importance to the student of the European scene. But he must be a critical student and a well-informed one.

L. DUDLEY STAMP.

The Irish Countryman: An Anthropological Study. By CONRAD M. ARENSBERG, Ph.D. [Pp. xii + 216.] (London: Macmillan & Co., Ltd., 1937. 10s. 6d. net.)

THIS delightful work forms an elaboration of lectures delivered last year at the Lowell Institute in Boston. It is interesting both in itself and as a study of anthropological method. It has become customary in so many schools for the idea to grow up that anthropology is limited to the study of primitive peoples and that work can only be done at the expense of a long journey to a distant spot, where the investigator is hampered by a tropical climate, and under normal circumstances by a complete ignorance of the language. Dr. Arensberg has given us a concrete example of the work which can be done amongst our own people and has shown that county Clare not less than the South Sea Islands is thoroughly deserving of anthropological study. It must be made clear at once that the problems of the countryside are not less difficult or baffling than those of the tropical forest, but the enquirer has the advantage of language and of a common cultural heritage by which to check his facts.

Dr. Arensberg's method, as indeed was inevitable from his form—lectures—has been to take certain aspects of the life of the peasant and to focus on them in turn, and further to exercise considerable selection in the use of his material. He begins by a general discussion of method, combined with a brief discussion of the human geography of southern Ireland. This he follows by a critical examination of the way in which the peasant earns his living, not so much from the point of view of economics, though this cannot of course be entirely avoided, as from the point of view of social organisation and what some have called "descriptive ethnography." This leads naturally to a description of the family and its relation to marriage and inheritance with special reference to the most important factor in all agricultural communities—land. The position and duties of the boys and men follows naturally, and

after work and duty has been described we have the relationship of the countryman to the shop and fair, where his pleasures and duties meet and also to that most important part of village life, the "pub." No discussion of Ireland, and especially southern Ireland, would be complete without something about the Good People, and here Dr. Arensberg gives us a most sympathetic chapter (Dr. Marett's name by the way is wrongly spelt on p. 180). It is a pity that the author of so careful a book did not take the trouble to make an index, and a simple map would have been of advantage. Anyone interested either in anthropology or Ireland should enjoy this book and it is to be hoped that one of Dr. Arensberg's lady pupils will write the missing chapter "Women and Girls."

L. H. D. B.

Records of a Yorkshire Manor. By SIR THOMAS LAWSON-TANCRED, Bt. [Pp. xii + 384, with 6 maps.] (London : Edward Arnold & Co., 1937. 21s. net.)

IN this book Sir Thomas Lawson-Tancred throws valuable light on the history of the sequestered village of Aldborough—a typical bit of unspoilt rural England some 17 miles from York, still boasting its stocks, maypole, and village pump—from the time when its streets echoed to the tramp of Roman legions.

By his scholarly and assiduous researches spread over many years, by his patient garnering of momentous trifles culled largely from original sources—Court Rolls, Parish Registers, Poll Tax Rolls, Correspondence, etc. etc.—the author has accumulated a wealth of material concerning the village with which the name of his family is so closely identified, far transcending its purely local interest.

In Part I of the book, the fourteen chapters of which are devoted to the social and economic history of the village (and of its church, manor house, and similar institutions), the collected documents, carefully collated and classified, trace the fortunes of what was formerly a "manor of ancient demesne," throwing into sharp relief its decline to the status of agricultural manor, whilst it was outstripped by Boroughbridge and other neighbouring towns. The manorial incidents pertaining to Aldborough are adequately dealt with by reference to the manor accounts, these symbols of feudalism being only finally extinguished in 1936. Some highly interesting rent rolls of the fifteenth and sixteenth centuries are given, as well as some very detailed household inventories; whilst another chapter focusses attention on the vexed problem of fishing rights on the River Ure and the Ouse—where salmon abounded in the sixteenth and seventeenth centuries.

Part II deals with the Parliamentary history of Aldborough and Boroughbridge, which achieved notoriety as "rotten boroughs" controlled by the Dukes of Newcastle. Here we have an admirable "untouched" picture, drawn from actual correspondence, of the bribery and corruption of the British parliamentary system until its more flagrant abuses were swept away by the Great Reform Bill, showing how two obscure villages, with but a handful of ratepayers or privileged "burgages," returned four members to Parliament whilst large manufacturing towns were totally unrepresented.

All told, this book is a valuable contribution to our social and economic literature. No fanciful or discursive story this, nor a medley collection of old wives' tales or village alehouse gossip which until recent years was so

often allowed to pass muster as "local history." Although, with such a wealth of material to draw upon, one regrets the noticeable omission of photographs from the first part of the book, it will prove a mine of information to students of social, economic, and constitutional history, and find a worthy place on the shelves of antiquarians.

D. W.

Half-Caste. By CEDRIC DOVER. [Pp. 324.] (London : Martin Secker & Warburg, Ltd., 1937. 10s. 6d. net.)

"TO-DAY there are no half-castes because there are no full-castes." The notion of a pure race is fallacious and fanciful, the product of childish ignorance and aggressive snobbery. The author "subscribes without qualification to the prevention of undeniably dysgenic matings but not to the conceit that color and economic success are indices of desirability." A large and most interesting section of this book presents a survey of the so-called half-castes existing in every part of the inhabited world, even the Esquimaux cannot claim to be free from impurity. It seems that miscegenation has operated from the earliest eras of the human race. In this survey the author especially considers the much-debated questions of the physical, cultural, and social effects which may arise as the results of miscegenosis, and which under reliable analysis are found to be largely illusory ; the mean values and mean variabilities of any particular attribute being not significantly different between half-castes and so-called full-castes ; and when real differences do appear they are derived from inequalities of environment and economic standards imposed by prejudice of the dominant race and especially exploitation under a capitalist system.

The author is himself a Eurasian and interested in the half-castes of India. He indicates that racial snobbery and competition for social status occurs as strongly among Eurasians as among Asians and Europeans. In fact, it seems that snobbery is a general expression for a universal human attribute ; it may perhaps exist among the apes ; a form of prestige lifting or selfishness, perhaps a form of self-preservation.

The author discusses the merits and failings of Eurasians. The chapter given to the life of the young Portuguese Indian, Derozio, with extracts from his poetry, is charming and a most illuminating contribution to the propaganda of Eurasian aims. When it is evidently the desire of the propagandist to remove prejudice it is well to avoid invective which is not the same as argument, and sarcasm which is not the same as humour.

It is a pity that on several occasions this excellent and interesting book should be blotted by expressions which will certainly hurt some readers and tend to deepen rather than lighten their prejudices.

The book is well written and easy to read. The catalogue of the prominent negroes in the Afro-American chapter is perhaps too long to be included in the story and might be more suitably placed in a footnote or appendix. There is a good and sufficient bibliography, and a useful index.

P. J.

Press Tool Making. By ERNEST PERRY. [Pp. viii + 92, with 34 figures.] (London : The Technical Press, Ltd., 1936. 3s. 6d. net.)

It is stated in the Preface that "the main object is to help those good fitters . . . to become toolmakers." Farther on, one reads that Technical terms

have been avoided as far as possible ! The writer stresses patience, thoroughness and care. The book however contains many blemishes among which may be found errors in composition, spelling (Fig. 10, p. 19, Fig. 11 p. 27, Fig. 29, p. 85) and draughtsmanship (Fig. 7, p. 10, Fig. 12, p. 31, Figs. 16, 17, pp. 49, 50).

After dealing with the Vernier, accurate drilling, tapping and screwing various types of press tools and jigs are illustrated and discussed. The chapter on hardening and tempering contains many sound hints on a subject of which the average toolmaker knows very little, but no guidance is given on the subject of the choice of quenching medium.

The book however abounds with useful information and hints on workshop procedure which should prove to be of great value to the press-tool maker, though in its present form it could be recommended to students only with reserve.

J. D. F.

BOOKS RECEIVED

(Publishers are requested to notify prices)

Modern Theories of Integration. By H. Kestelman, M.Sc., Lecturer in Mathematics, University College, London. Oxford : at the Clarendon Press ; London : Humphrey Milford, 1937. (Pp. viii + 252.) 17s. 6d. net.

Introduction to the Theory of Fourier Integrals. By E. C. Titchmarsh, F.R.S., Savilian Professor of Geometry in the University of Oxford. Oxford : at the Clarendon Press ; London : Humphrey Milford, 1937. (Pp. x + 390.) 17s. 6d. net.

Lectures on the Mathematical Theory of Electricity. By F. B. Pidduck. Oxford : at the Clarendon Press ; London : Humphrey Milford, 1937. (Pp. viii + 110, with 119 figures.) 7s. 6d. net.

A Text-Book of the Differential Calculus. By S. Mitra, M.A., and G. K. Dutt, M.A. Cambridge : W. Heffer & Sons, Ltd., 1937. (Pp. xiv + 302, with 20 figures.) 10s. net.

A Treatise on the Analytical Dynamics of Particles and Rigid Bodies. With an Introduction to the Problem of Three Bodies. By E. T. Whittaker, Professor of Mathematics in the University of Edinburgh. Fourth edition. Cambridge : at the University Press, 1937. (Pp. xiv + 456.) 25s. net.

An Introduction to the Theory of Statistics. By G. Udny Yule, C.B.E., M.A., F.R.S., Fellow of St. John's College, and formerly Reader in Statistics, Cambridge, Honorary Vice-President of the Royal Statistical Society, and M. G. Kendall, M.A., formerly Mathematical Scholar of St. John's College, Cambridge, Fellow of the Royal Statistical Society. Eleventh edition. London : Charles Griffin & Co., Ltd., 1937. (Pp. xiv + 570, with 55 figures, 4 folding plates and numerous tables.) 21s. net.

Trigonometry. Part II : Higher Trigonometry. By T. M. MacRobert, M.A., D.Sc., Professor of Mathematics, and William Arthur, M.A., Lecturer in Mathematics, in the University of Glasgow. London : Methuen & Co., Ltd., 1937. (Pp. x + 143, with 20 figures.) 4s. 6d.

Cosmological Theory. By G. C. McVittie, M.A., Ph.D., F.R.A.S., Reader in Mathematics in the University of London, King's College. Methuen's Monographs on Physical Subjects. London : Methuen & Co., Ltd., 1937. (Pp. viii + 103.) 2s. 6d. net.

- The Distribution of the Stars in Space.** By Bart J. Bok, Harvard Observatory. *Astrophysical Monographs.* U.S.A.: University of Chicago Press; Great Britain and Ireland: Cambridge University Press, 1937. (Pp. xvi + 124, with frontispiece, 12 figures and 19 tables.) 11s. 6d. net.
- Planeten-Photographie.** Von Dr. H. J. Gramatzki. Berlin and Bonn: Ferd. Dümmlers Verlag, 1937. (Pp. 71, with 21 figures.) Price abroad, RM. 2.70.
- An Introduction to Weather and Climate.** By Glenn T. Trewartha, Associate Professor of Geography, University of Wisconsin. New York and London: McGraw-Hill Publishing Co., Ltd., 1937. (Pp. x + 373, with 7 folding plates and 108 figures.) 18s. net.
- Synoptic and Aeronautical Meteorology.** By Horace Robert Byers, Sc.D., In Charge of Air-Mass Analysis Section, U.S. Weather Bureau. New York and London: McGraw-Hill Publishing Co., Ltd., 1937. (Pp. x + 279, with 58 figures, 10 tables and 6 maps.) 21s. net.
- Introduction to Ferromagnetism.** By Francis Bitter, Associate Professor of the Physics of Metals at the Massachusetts Institute of Technology. New York and London: McGraw-Hill Publishing Co., Ltd., 1937. (Pp. xii + 314, with 147 figures and 11 tables.) 24s. net.
- Low Temperature Physics.** By M. and B. Ruhemann. Cambridge: at the University Press, 1937. (Pp. x + 313, with 121 figures, including 2 plates, and 26 tables.) 18s. net.
- Sound. A Text Book.** By Arthur Taber Jones, Professor of Physics, Smith College. New York: D. van Nostrand Co., Inc.; London: Chapman & Hall, Ltd., 1937. (Pp. xii + 450, with 141 figures.) 20s. net.
- Sound Waves. Their Shape and Speed. A Description of the Phonodeik and its Applications and a Report on a Series of Investigations made at Sandy Hook Proving Ground.** By Dayton Clarence Miller, D.Sc., D.Eng., LL.D., Professor of Physics, Case School of Applied Science. New York and London: Macmillan & Co., Ltd., 1937. (Pp. xii + 164, with frontispiece and 64 figures.) 12s. net.
- A Text-Book of Light.** By G. R. Noakes, M.A., A.Inst.P., Senior Science Master, Giggleswick School. London: Macmillan & Co., Ltd., 1937. (Pp. x + 355, with 276 figures and 1 folding chart.) 6s.
- Fundamentals of Physical Optics.** By Francis A. Jenkins and Harvey E. White, Associate Professors of Physics, University of California. New York and London: McGraw-Hill Publishing Co., Ltd., 1937. (Pp. xiv + 453, with 272 figures and 14 tables.) 30s. net.
- Atomic Artillery. Modern Alchemy for Everyman.** By John Kellock Robertson, F.R.S.C., Professor of Physics, Queen's University, Kingston, Canada. New York: D. van Nostrand Co., Inc.; London: Macmillan & Co., Ltd., 1937. (Pp. xiv + 177, with 26 figures, including 6 plates, and 6 tables.) 10s. 6d. net.
- Atomic Spectra and Atomic Structure.** By Gerhard Herzberg, Research Professor of Physics, University of Saskatchewan. Translated with the co-operation of the author by J. W. T. Spinks, Assistant Professor of

- Chemistry, University of Saskatchewan. London and Glasgow : Blackie & Son, Ltd., 1937. (Pp. xvi + 257, with 80 figures and 21 tables.) 18s. 6d. net.
- The Fine Structure of Matter. The Bearing of Recent Work on Crystal Structure, Polarization and Line Spectra. Vol. II of a Comprehensive Treatise of Atomic and Molecular Structure. Part I : X-Rays and the Structure of Matter. By C. H. Douglas Clark, D.Sc., A.R.C.S., A.I.C., D.I.C., Assistant Lecturer in Inorganic Chemistry in the University of Leeds. London : Chapman & Hall, Ltd., 1937. (Pp. xxxvi + 252, with 59 figures and 34 tables.) 15s. net.
- The World of Atoms. Twelve Non-Mathematical Lectures. By Arthur Haas, Ph.D., Professor of Physics in the University of Vienna, at present Professor of Physics in the University of Notre Dame (U.S.A.). Second edition. Translated by George B. Welch, Ph.D., Northeastern University. New York : D. van Nostrand Co., Inc. ; London : Chapman & Hall, Ltd., 1937. (Pp. xiv + 183, with 54 figures and 6 tables.) 10s. 6d. net.
- Textbook of Thermodynamics. By Paul S. Epstein, Professor of Theoretical Physics, California Institute of Technology. New York : John Wiley & Sons, Inc. ; London : Chapman & Hall, Ltd., 1937. (Pp. xii + 406, with 64 figures and 58 tables.) 17s. 6d. net.
- Engineering Mechanics : Dynamics. By S. Timoshenko, Professor of Theoretical and Applied Mechanics, Stanford University, and D. H. Young, Assistant Professor of Engineering Mechanics, University of Michigan. New York and London : McGraw-Hill Publishing Co., Ltd., 1937. (Pp. xii + 323, with 314 figures.) 15s. net.
- Elementary Engineering Science. By Arthur Morley, O.B.E., D.Sc., M.I.Mech.E., formerly Professor of Mechanical Engineering in University College, Nottingham, and Edward Hughes, Ph.D., D.Sc., M.I.E.E., Head of the Engineering Department, Brighton Technical College. London, New York, Toronto : Longmans, Green & Co., 1937. (Pp. xii + 290, with 158 figures.) 3s. 6d.
- Hydraulics. A Text on Practical Fluid Mechanics. By R. L. Daugherty, A.B., M.E., Professor of Mechanical and Hydraulic Engineering, California Institute of Technology. Fourth edition. New York and London : McGraw-Hill Publishing Co., Ltd., 1937. (Pp. xiv + 460, with 318 figures and 15 tables.) 21s. net.
- The Origin and Constitution of Matter. By Howard A. Redfield. Published by George Hillenbrand, Monterey Park, California. (Pp. 46, with 40 figures.)
- A Comprehensive Treatise on Inorganic and Theoretical Chemistry. By J. W. Mellor, D.Sc., F.R.S. Vol. XVI : Pt and General Index. London, New York, Toronto : Longmans, Green & Co., 1937. (Pp. x + 811, with 94 figures.) 63s. net.
- Modern-Life Chemistry. By Frank O. Kruh, Soldan High School, St. Louis, Missouri, Robert H. Carleton, Summit High School, Summit, New Jersey, and Floyd F. Carpenter, Stivers High School, Dayton, Ohio. Edited by W. R. Teeters, Supervisor of Physical and Biological Sciences, St. Louis Public Schools. New York : J. B. Lippincott Co., 1937. (Pp. xxvi + 734, with frontispiece, 1 plate, 359 figures and 46 tables.) 8s. 6d. net.

- The Properties and Functions of Membranes, Natural and Artificial. A General Discussion.** Reprinted from the "Transactions of the Faraday Society." London and Edinburgh: Gurney & Jackson for the Society, 1937. (Pp. 911-1151, with numerous figures and tables.) 12s. 6d. net.
- Catalytic Processes in Applied Chemistry.** By T. P. Hilditch, D.Sc., F.I.C., Campbell Brown Professor of Industrial Chemistry in the University of Liverpool, and C.C. Hall, M.Sc., Ph.D., A.I.C., of the Staff of the Fuel Research Station, Department of Scientific and Industrial Research. Vol. II of a Series of Monographs on Applied Chemistry, under the Editorship of E. Howard Tripp, Ph.D. Second edition. London: Chapman & Hall, Ltd., 1937. (Pp. xxii + 478.) 25s. net.
- The Chemistry and Technology of Rubber.** Carroll C. Davis, Editor, John T. Blake, Associate Editor. American Chemical Society Monograph Series. New York: Reinhold Publishing Corporation; London: Chapman & Hall, Ltd., 1937. (Pp. ii + 941, with 109 figures and 155 tables.) 75s. net.
- Protective Films on Metals.** By Ernest S. Hedges, M.Sc., Ph.D., D.Sc., A.I.C., late Darbshire Research Fellow of the Victoria University of Manchester. Second edition. Vol. V of a Series of Monographs on Applied Chemistry under the Editorship of E. Howard Tripp, Ph.D. London: Chapman & Hall, Ltd., 1937. (Pp. xvi + 397, with 53 figures, including 15 plates.) 21s. net.
- Metallography.** By Cecil H. Desch, D.Sc., Ph.D., F.R.S., Superintendent, Metallurgy Department, National Physical Laboratory. Fourth edition. Textbooks of Physical Chemistry. London, New York, Toronto: Longmans, Green & Co., 1937. (Pp. viii + 402, with 18 plates and 145 figures.) 21s. net.
- Principles of Chemical Engineering.** By William H. Walker, Warren K. Lewis, William H. McAdams, and Edwin R. Gilliland, Professors of Chemical Engineering, Massachusetts Institute of Technology. Third edition. Chemical Engineering Series. New York and London: McGraw-Hill Publishing Co., Ltd., 1937. (Pp. xii + 749, with 227 figures.) 30s. net.
- The Art of Carburation in Theory and Practice, including Fuel Distribution in Manifolds. For Designers and Engineers.** By Robert W. A. Brewer. London: The Technical Press, Ltd., 1937. (Pp. xii + 176, with 151 figures and 82 tables.) 21s. net.
- Organic Chemistry.** By Frank C. Whitmore, Research Professor of Organic Chemistry, The Pennsylvania State College. New York: D. van Nostrand Co., Inc.; London: Chapman & Hall, Ltd., 1937. (Pp. x + 1080.) 40s. net.
- Systematic Organic Chemistry. Modern Methods of Preparation and Estimation.** By William M. Cumming, D.Sc., F.I.C., "Young" Professor of Technical Chemistry in the Royal Technical College, Glasgow, I. Vance Hopper, Ph.D., A.R.C.Sc.I., F.I.C., Lecturer on Organic Chemistry in the Royal Technical College, Glasgow, and T. Sherlock Wheeler, Ph.D., B.Sc., F.R.C.Sc.I., F.I.C., Professor of Organic Chemistry, Imperial College of Science, Bombay. Third edition revised by William M. Cumming and I. Vance Hopper. London: Constable & Co., Ltd., 1937. (Pp. xxvi + 547, with 85 figures.) 25s. net.

- Sterols and Related Compounds.** By E. Friedmann, M.D., Ph.D. Cambridge: W. Heffer & Sons, Ltd., 1937. (Pp. vii + 100.) 7s. 6d. net.
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SCIENCE PROGRESS

REACTIONS AT LIQUID SURFACES

By ERIC K. RIDEAL, M.B.E., M.A., D.Sc., F.R.S., F.I.C.

Professor of Colloid Science in the University of Cambridge

REACTIONS in monolayers are of interest, not only because they include a number of catalytic reactions taking place at solid surfaces, but also because there appears to be at liquid interfaces, and especially in gel-like monolayers, a close similarity to many biological reactions occurring *in vivo*.

The important factors to consider in these reactions are the possible influences of molecular orientation, and the surface or capillary forces, of which molecular orientation is one, but not the only manifestation, both on the reaction velocity and on the conditions of equilibrium. If we regard the speed of a reaction as being determined both by the collision number and by either the energetics of the mutual approach of the reactants, or by the configurations of reactants and transition complex respectively, it is evident that reactants in surfaces differ from those in bulk phase; in the latter case control can only be exercised over the collision number and temperature, in the former it is frequently possible to regulate at least in some measure the factors bound up in configuration.

One of the simplest cases to consider is to be found in the oxidation of the double bond in unsaturated long-chain acids by dilute potassium permanganate. In bulk phase this oxidation proceeds smoothly through a series of stages—we can confine ourselves to the initial one of forming the dihydroxy saturated acid. In a monolayer of an unsaturated acid it is evident that we can control the accessibility of the double bond to the substrate by simple expansion or compression of the film. In Table I are given the oxidation rates of monolayers of oleic and petroselenic acids, two typical unsaturated acids, as a function of the film density.

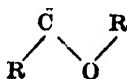
TABLE I

n molecules/sq. cm. $\times 10^{-14}$	Rate of oxidation k in min. ⁻¹	
	Oleic.	Petroselenic.
1	0.18	0.2
1.5	0.17	0.2
2	0.08	0.2
2.5	0.04	0.18
3	0.02	0.13
3.5	very small	0.025

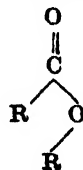
It will be seen that there is a remarkable diminution in the reaction velocities when the films are compressed to the stage at which we can infer from measurements of the film properties that the double bonds are being raised from the surface and buried in the oil phase of the film. In considering a hydrocarbon chain having a double bond in the middle we note if we construct the models that the so-called *cis* form causes a bend in the chain whilst the linear character is preserved in the *trans* form. This leads further to the view that whilst the *trans* form can pack closely with its neighbours, and indeed as found experimentally form mixed films with saturated chains, this is impossible for the *cis* form along its length, and in consequence the *cis* acids form more expanded films and are more accessible to reaction under similar conditions of temperature and pressure.

The difference in behaviour and in chemical reactivities between the *cis* and *trans* modifications when these are present in the chain is thus revealed in films, but not in the bulk phase. It is interesting to note the great differences in properties of monolayers containing both protein and triolein or tripalmitin respectively. At the same time, differences in chemical reactivities between *cis* and *trans* modifications in the reactive head groups are revealed when we examine these in monolayers. Thus whilst it is not surprising that both the film properties and reactivities with dilute bromine water of dicetyl maleate and dicetyl fumarate are different, yet similar differences are found in the esters. In non-polar solvents the strong interaction between the polar groups prevents free rotation about the C—O bond and the normal configuration is the *trans* form (A)

(A)



(B)



whereas in aqueous substrates we may find the *cis* form (B) present as well.

The configuration obtaining in the film is dependent on the constitution of the ester and the film pressure. The following areas (A^2) and configurations have been obtained for a series of esters in the form of monolayers on *N*.NaOH together with the unimolecular velocity constants (k) for hydrolysis at 20° C. as well as the value of the vertical component of the apparent dipole in the head group expressed in milli-Debyes (μ).

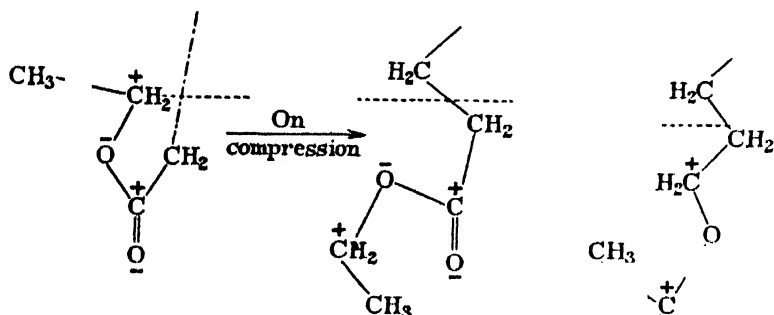


FIG. 1.

$\mu_{\text{obs.}} = 535$ milli-Debyes
 $\mu_{\text{calc.}} = 525$ "
 $A > 72 \text{ \AA}^2$ "
 $K = 0.04 \text{ min.}^{-1}$

FIG. 2.

$\mu_{\text{obs.}} = 193$ milli-Debyes
 $\mu_{\text{calc.}} = 198$ "
 $A = 20 \text{ \AA}^2$ "
 $K = 0.005 \text{ min.}^{-1}$

FIG. 3.

$\mu_{\text{obs.}} = 502$ milli-Debyes
 $\mu_{\text{calc.}} = 525$ "
 $A = 23 \text{ \AA}^2$ "
 $K = 0.15 \text{ min.}^{-1}$

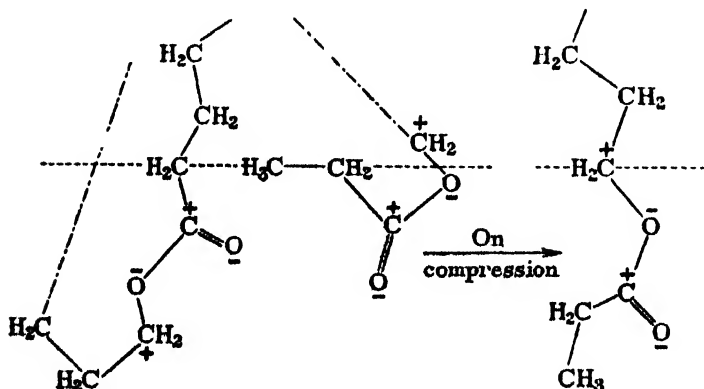


FIG. 4.

$\mu_{\text{obs.}} \approx 0$ milli-Debyes
 $\mu_{\text{calc.}} = 7$ "
 $A = 41 \text{ \AA}^2$ "
 $K \approx 0.18 \text{ min.}^{-1}$

FIG. 5.

$\mu_{\text{obs.}} = 500$ milli-Debyes
 $\mu_{\text{calc.}} = 525$ "
 $A = 65 \text{ \AA}^2$ "
 $K = 0.084 \text{ min.}^{-1}$

FIG. 6.

$\mu_{\text{obs.}} = 334$ milli-Debyes
 $\mu_{\text{calc.}} = 320$ "
 $A = 21 \text{ \AA}^2$ "
 $K = 0.021 \text{ min.}^{-1}$

Note. In order to show the orientation with respect to the water surface, the latter is indicated by the dotted horizontal line, which, however, must *not* be taken as the true depth of immersion.

We note the hydrolysis velocity constants differ very considerably from ester to ester. If we examine the kinetics of these reactions as a function of the compression and state of the film we find that at high compressions and in the condensed states the energy of activation is the same for all the esters, *viz.* *ca.* 17,600 cals./gm. mol., but in the expanded state the apparent energies of activation as well as the steric factor p in the expression $k = pZe^{-\frac{E}{RT}}$ varies with the ester and with the compression as is shown in the following data for trilaurin on $N.NaOH$. In this equation, the well-known expression for the velocity constant (k) of a reaction, $k = pZe^{-\frac{E}{RT}}$, p is the steric factor, Z the collision number or $\frac{kT}{h}$ in Eyring's modification of the reaction mechanism and E the energy of activation.

F dynes/cm.	k $\times 10^3$ sec. $^{-1}$	E cals./gm. mol.	p
5.4	0.745	10,000	1.1 10^{-4}
10.8	0.787	13,200	3.1 10^{-4}
10.2	0.671	16,100	4.1 10^{-3}

The data indicate that at high pressures and in condensed films the reaction velocity observed is that determined by a purely kinetic collision mechanism, but it is clear that at low pressures and in the expanded state the apparent activation energy is reduced from some 17,600 cals./gm. mol to the value which it has in bulk phase so that a change in mechanism takes place on compression of the film. No such changes in energy are observed in the hydrolysis of a symmetric structure such as a lactone in a monolayer. Although the evidence is not so conclusive as is the case with the esters, we have reason to believe that the acid head group can likewise exist in both the *cis* and *trans* configurations in monolayers. These two types are clearly differentiated by possessing very different values for their phase boundary potentials. We thus note that in these relatively simple reactions, limitations can be imposed on both the steric

and energetic factor by controlled alteration in the molecular orientation of one of the reactants. This is likewise the case where we are dealing with the formation of and the reactions of polymeric or macromolecular substances. Numerous types of linear macromolecules, both synthetic such as the ω -hydroxy esters, methyl methacrylate, or natural such as cellulose, rubber, proteins, can by suitable methods be extended into monolayers at interfaces. Molecules in this extended or flat position are said to be in the homalic state. Homalic monolayers are the precursors of membranes, and as such are of peculiar interest to biologists. The kinetics of the formation of linear macromolecules may be examined both in bulk phase and in monolayers. We can recognise several very different types. To mention but two important cases: in the first we have a reaction involving three distinct stages, (a) initiation, (b) propagation, (c) termination. In the second we have an interaction to form a complex AB which can then associate to form the macromolecule $(AB)_n$ containing n simple complexes linked together. This second reaction may likewise be regarded as one in which a reactant B forms bridges between two reactive groups in the A molecules. In both cases, as we should anticipate, the steric or p terms are very small. An example of the first type is found in the polymerisation of butadiene or methyl methacrylate to form a synthetic macromolecule. The growth of the polymer at a water surface in the presence of the vapour of the reactant proceeds until the surface is covered with polymer. It is found that the steric or p term for the interface reaction is much larger than for the bulk phase reaction, although the energy of activation for initiation due to the formation of a labile peroxide is identical. As a result the rate of polymerisation at interfaces is much greater than for identical activities of reactants in bulk phase.

As examples of the second type, we may mention the bridging over by means of oxygen of the unsaturated linkages in esters comprising the drying oils or the interaction of sodium polysulphide with dihalogen derivatives of the hydrocarbons to form the polymeric thiokols. In both cases the reaction kinetics are so complicated that it would appear to be almost a hopeless task to attempt an elucidation in bulk phase. At an interface, however, it has been found possible to dissect these reactions into their components, and an exact analysis of the process of drying of an oil has been made.

It was found that there was first formed a labile peroxide involving an energy of activation of 6,000 cal./gm. mol., the velocity

of formation of which could be calculated from simple kinetic collision considerations involving a p term of unity. This unstable peroxide could then polymerise to form a macromolecule involving some ten units of the original unsaturated glyceride, or could be converted into a more stable peroxide which only underwent chain "propagation" when a much higher energy of activation (*ca.* 20,000 in comparison with 5000 cal./gm. mol.) was involved. By confining the growth of these macromolecules to two dimensions instead of three, the mechanism of initiation inhibitors and accelerators, as well as various types of chain breaking and chain linking molecules can be examined in detail. We may cite the inhibitory efficiencies of a series of esters in the polymerisation of the peroxide of the maleic anhydride of β -elæosterin. Ethyl myristate, on account of its saturated character, is a complete inhibitor or chain blocker $\{I = 100\}$ whilst the unsaturated esters possess a finite probability of being incorporated in the growing chain. The data obtained were:

Ester.	Inhibitory Efficiency.
	I
Ethyl myristate	100
Methyl linoleate	40
Ethyl linoleate	29
Methyl β -elæostearate	24

So far no attempts to synthesise macromolecules or polymers of the amino acids in monolayers have been successful, but it can be noted that ring closure, one of the most serious limitations to the formation of macromolecules in bulk phase, is practically eliminated at interfaces. On the other hand, it has been found possible to spread a number of native proteins and examine their behaviour and reactivities. Whilst proteins may form films by allowing dilute solutions to stand, they may be spread on suitable substrates, either from the carefully desiccated solid, or from extremely dilute solutions. The rate of spreading to uniform monolayers is dependent upon the pH and presence of suitable salts in the substrate. Thus casein spreads with extreme slowness on buffers at the isoelectric point, and myosin, the muscle protein, will not spread on water unless more than 1.8 per cent. of sodium chloride be present, but will spread with the greatest facility on substrates containing lactic or other hydroxy acids.

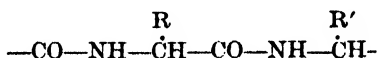
The following suggestive table was obtained by Gorter for the concentration of ions promoting the spreading of proteins on water,

and the concentration of ions in the body fluids, i.e. in serum water and muscle water.

Ion.	Mille equiv./litre.		Mille equiv./litre showing Equal Spreading Effects.
	In Serum Water.	In Muscle Water.	
Na	154.0	48.0	160.0
K	5.3	112.5	80.0
Ca	5.1	5.2	4.0
Mg	2.8	23.9	4.0
Glutathione .	nil	1	1

In view of the importance of the structure on chemical reactivity it is worth while considering some points in connection with the possible structure of such monolayers.

We may regard the fundamental protein unit as consisting of a polypeptide chain

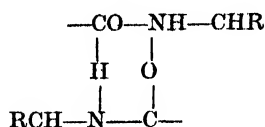


the side chains terminating either in polar or non-polar groups. The properties of the films in their greatest extension suggest that the chains are lying on the surface with the side chains extended on the surface, at least those side chains which terminate with non-polar groups. In this state the films are liquids. The pressure limits of these continuous but extended monolayers are extremely low, and for this reason their existence has often been overlooked. On slight increase in pressure, a contraction in area takes place and the films become gelatinous, but are still compressible. This sol-gel transition is not readily reversible. It seems most probable that the backbones of the chains spread in the α -keratin or non-extended form are now in close proximity to one another and that the side chains are orientated vertically, those with polar terminations in the liquid and the hydrocarbon side chains forming a hydrophobic layer above. The lateral cohesion between the units is brought about chiefly by interaction of the polar reactive ends

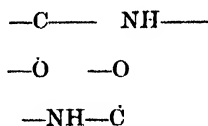
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of side groups, but also between any free $\text{—CO—NH—}\overset{\text{R}}{\underset{|}{\text{CH}}}\text{—}$ units in separate protein macromolecules or between similar units in one chain which has undergone a folding process.

The nature of the ketoimido interlinkage is not known. It may be a hydrogen bond of the type



or more likely an ammonium linkage.



It is uncertain whether these gel monolayers are really macromolecules or highly viscous liquids in the sense that the salt and ketoimido interlinkages are capable of being made and broken reversibly under strain, but some evidence suggests that this is the case. On further compression the protein may be removed from the surface in the form of filaments which are not redispersible in solution. We note that these filaments must consist of bundles of polypeptide chains with parallel chain axes in the folded α -keratin form, the polar groups turned in to the fibril axis, and the non-polar groups turned out to the periphery of the fibre, for they are hydrophobic units and non-dispersible by salts. We may observe that these fibrils are the reverse of native fibrillar and dispersible proteins, since on solution we might anticipate that the non-polar side chains of the macromolecules forming the native proteins would be turned in, and the polar side chains turned out to the periphery. We may regard these protein films as a prototype of either cyclols or plates consisting of duplex protein monolayers, the layer between the two sheets of chains consisting of the non-polar side chains, as the limit of the denatured form of native proteins. Denaturation, according to this view, is due to a rotation of parts of the macromolecules about their long axes, taking some polar side chains from the periphery to the interior and some non-polar side chains from the interior to the periphery. Clearly alkaline and acid denaturation will cause the emergence of side chains terminating in different polar groups. An essential for this denaturation by rotation is the temporary breakage, at least of the salt and any of the ketoimido linkages which hold the macromolecules together laterally in the fibril or sheet. Such breakage can be accomplished thermally, by saturation of the solution with substances having an affinity for

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the $\text{—CO—NH—}\dot{\text{C}}\text{H—}$ group, such as urea, or by the addition of materials which exert a peptising action by penetration—a point we shall refer to later. The breakage is evidently most easily effected when the salt linkages on the exterior surface of the spheroid or plate are likewise broken, *i.e.* when the protein is outside the Svedberg stability limits, *i.e.* those hydrogen ion concentrations within which the protein behaves as a stable unit.

We note that the gel structure is very compressible, suggesting that a process of reversible or partly reversible dehydration must be taking place. Clearly the macromolecular chains cannot be so

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orientated that every $\text{—CO—NH—}\dot{\text{C}}\text{H—}$ group is interlocked with two neighbours and many chains must be folded and even crossing one

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another. Again the cross-section of an extended $\text{—CO—NH—}\dot{\text{C}}\text{H—}$ group is only some 16\AA^2 , thus only if every side chain were alternately polar and non-polar could even extension, and thus maximum close packing, result. It therefore follows that those proteins in which the chains contain a number of non-polar or of polar groups in sequence must have a different compressibility from those proteins which have a regular alternating arrangement.

Although the chemical properties of protein monolayers have not been extensively examined, the available evidence supports the suggested structure. Thus protein monolayers are readily attacked by proteoclastic ferments, the temperature coefficients and *pH* optima for reaction being identical with the bulk phase reactions. It is possible to form complexes between the amino groups of the side chains and phenolic derivatives such as gallic acid. If a number of galloyl groups are joined together by means of a sugar ring, we can anchor a number of the amino groups to one tannin molecule and convert the elastic gelatinous monolayer into a rigid non-elastic skin. The amino groups can be linked together in a similar manner by means of polysilicic acid formed in the substrate by the hydrolysis of sodium silicate.

The implications and consequences of molecular orientation existing in monolayers are no less profound in photochemical reactions than in the chemical processes outlined above. It is found that the light absorption in the monolayer defined as the molecular extinction coefficient in the monolayer is equal to $3/2 \sin^2 \theta$ times the bulk coefficient, where θ is the angle between the dipole axis of the absorbing system and the direction of the incident light, and

is naturally capable of variation on compression or extension of the film. In the following table are given the apparent quantum efficiencies of the photochemical hydrolysis of stearic anilide in a monolayer on aqueous hydrogen chloride as substrate, and their variation with the molecular areas.

Apparent Quantum Efficiency.	Molecular Area in \AA^2 .
0.5	27.6
0.4	28
0.2	28.5
0.16	30
0.10	31
0.04	32
0	33

In the case of proteins the aromatic side chains tyrosine, phenylalanine, tryptophane and histidine are the only important groups where there is appreciable light absorption at $\lambda > 2400 \text{ \AA}$., in this region the molecular extinction coefficient being of the order of 10^3 to 10^4 . These groups are consequently chromophoric portions in the extended molecule and it is reasonable to suppose that on illumination the peptide linkages are split only at those portions where the chromophoric groups exist. By examination of the change in phase boundary potential on illumination of monolayers of egg albumin with light of wave length $\lambda = 2854$, it is concluded that some 8.2 per cent. of the total number of CO—NH groups in the monolayer are split by hydrolysis. This is indeed very close to the numerical proportion of aromatic amino acid residues (7 per cent.) present in this protein. The quantum efficiency of this process of photochemical protein hydrolysis is likewise capable of variation with the compression of the film. It is interesting to note that in the process of fragmentation of the proteins into shorter chain proteoses by this selective induced hydrolysis photochemical oxidation changes occur as well, and it has been shown that the glycyl tyrosin fraction is eventually converted into a melanin-like pigment. We thus observe that a whole series of oxidative and hydrolytic changes including an indol ring closure can be brought about by suitable radiation as well as by the well-known enzymitic processes.

In the above case we are dealing with the excitation of chromophors which are part of the natural structure of the proteins. It is possible to incorporate alien chromophors into the protein and bring about similar photochemical actions by means of these new chromophors. We shall have occasion to discuss the mechanism of the process of incorporation in more detail later, but for the present we observe, for example, that the injection of a small quantity of

hæmatoporphyrin under a protein monolayer will sensitise the monolayer to reaction in visible light in the absorption region of the hæmatoporphyrin. The attachment of the hæmatoporphyrin to the protein monolayer occurs in all probability as in gallic acid by interaction of its hydroxyl group with the amine and ionised carboxyl groups of the protein. This observation is confirmed by the fact that many phenol ring and secondary alcohol-containing compounds, including such substances as cholesterol and the various œstrogenic substances, such as the pinacols and 4:4'-dihydroxystilbenes all readily form complexes with proteins. It is found that the stability of the protein, phenol, or alcohol complex is largely determined by the structure of the ring system of the alcohol. Each complex naturally possesses its own characteristic absorption spectrum, not markedly different from that of the free alcohol. We thus have a simple method of sensitising proteins to radiation in the visible portion of the spectrum by means of hæmatoporphyrin, and in the near ultra-violet region by phenolic and secondary alcoholic groups attached to suitably large ring systems. It is found, for example, that a variety of complex phenolic compounds are readily adsorbed by the proteins in the cell walls of paramœcia, which are then sensitised to radiation in the near ultraviolet and rapidly destroyed.

It is also worthy of note that lenses or crystals of many hydrocarbons, including the carcinogenic ones, on a water surface or in benzene solution, on irradiation within the limits of their ultra-violet absorption spectrum, undergo chemical action, probably oxidative fission of part of the ring system, the resulting oxy-compounds spread rapidly and are in part water soluble. Injection of the soluble portion under a protein monolayer reveals the fact that some portion reacts with the protein, giving changes similar to those of the complex aromatic phenols, and the complexes are photosensitive. Thus the irradiation of 4 mgm. of the carcinogenic hydrocarbon benzpyrene for one and a half hours with radiation of $\lambda = 2654$ at a rate of 10^{14} quanta per second, and extraction of the irradiated product with water, resulted, on injection of the aqueous solution under a protein monolayer, of a change in phase boundary potential of 50 m.v. of the same order as that produced by somewhat stronger solutions of the 4:4'-dihydroxystilbene. These observations suggest the following series of reactions in the photodynamic action of the carcinogenic hydrocarbons:

- (1) Photochemical ring fission and oxidation to a secondary alcohol group of the hydrocarbon.
- (2) Complex formation of the oxidised product with the amino or ionised carboxy group of the protein.

(3) Photochemical hydrolysis and oxidation at those portions of the protein to which the chromophor is attached. The photochemical efficiencies of (1) and (3) require detailed examination as well as the stability of the complex (2) as determined by the structure of the original hydrocarbon.

This process of incorporation of alien chromophors in the macromolecular (homalic) protein monolayers is only one example of a reaction which is very common in orientated monolayers. Thus, if dilute solutions of various reactants be introduced beneath a monolayer, a primary reaction may occur as detected by a change in the phase boundary potential. This primary action is characterised by adsorption beneath the monolayer by means of an electrical interaction between the accessible reactive groups of the film forming material and the reactive groups of the material injected. If the material injected contains several reactive groups, these may link up with several molecules of the surface film forming complexes with multi-point contact; examples of such are the tannins, silicic acid or the dye Janus green underneath films of amines or of proteins or of the polymeric phosphoric acid under a film of stearic acid in the presence of calcium ions, when a rigid network of a calcium stearate phosphate is formed. Little is known about the kinetics of such reactions, but it may be observed that the apparent rate of reaction of pentadigallyl glucose with a protein monolayer is much greater than for the more rapidly diffusing and presumably per group equally reactive digallic acid. Such macromolecular adsorbed complexes, when formed on the surfaces of biological cells, cause agglutination and sensitisation, but do not effect lysis.

In suitable systems this primary interaction is followed by a secondary reaction which we have termed film penetration. If, for instance, under a monolayer of orientated molecules, consisting of a large hydrophobic protein or "tail," and a polar group or "head" similar molecules be injected into the underlying solution, the following alteration in the surface potential and pressures (at constant area or with suitable precautions and modifications of technique, the areas at constant pressures can be measured) of the film forming molecules may take place.

- (1) If there is no association between the polar groups of the film and injected molecules, no or only a small alteration in the film characteristics is noticed, even if the "tails" are mutually soluble.
- (2) If there be association between the polar groups, but none between the "tails" or hydrophobic groups, then an

adsorption of the injected molecules on to the film molecules takes place with a consequent change in surface potential. The surface pressure only changes if multi-point contact takes place which results in a contraction (or more rarely a slight expansion) of the film.

- (3) If there be association between the respective head groups and the "tails," then each polar group of the film forming molecule anchors a polar group of the injected molecule. The hydrophobic portion of the injected molecule associates with the hydrophobic group of the film-forming molecule and thus penetration of the monolayer takes place. The number of molecules in the monolayers is thus suddenly doubled and the surface pressure (or area) consequently rises sharply whilst the surface potential rises or falls to the value obtained with a film composed of an equimolecular mixture of the two substances.

Either simple or complex molecules may be involved in these reactions. Thus an extremely dilute solution of sodium cetyl sulphate injected beneath monolayers of substances such as the primary cetyl alcohol or the biologically important cholesterol or sphingomyelin cause a rapid extension of the film due to the penetration of the sodium cetyl sulphate to form an equimolecular mixed film. Information as to the extent of the interaction between the head groups can be obtained from measurements of the phase boundary potential, whilst the viscosity of the resulting liquid (or rigidity if solid) film provides us with information concerning both the lateral adhesion of the hydrophobic chains or ring system and the mechanical interaction of the head groups.

It is clear that these complex forming and penetrative reactions which are revealed by the film technique open up a new chapter of reaction systems and from consideration of the few which have been studied their similarity to biological processes seems most striking.

RECENT WORK ON THE DIGESTION OF CELLULOSE AND CHITIN BY INVERTEBRATES

BY C. M. YONGE, D.Sc.

Professor of Zoology in the University of Bristol

1. INTRODUCTION

IN a previous volume of SCIENCE PROGRESS (Yonge, 1925) a résumé was given of literature on digestion of cellulose by invertebrates. The addition of a significant volume of work on this interesting subject during the years which have since elapsed justifies the production of a revised and extended review. To this has been added an account of work on the digestion of chitin by invertebrates. Although only the results of recent work are here discussed a full list of references is given.

It is necessary first to state that attention is restricted to work on true cellulases not, therefore, including lichenase which breaks down the hemicellulose, lichenin, a substance which is not structurally identical with cellulose (see Haas and Hill (1928)) and is hydrolysed by enzymatic action to lichotriose instead of to cellobiose (Karrer and Lier (1925)). Karrer and his co-workers (see Vonk (1937) for full literature list and general summary of this work) consider that the cellulase and the hemicellulase (lichenase) present in the gut of the snail, *Helix*, are identical, but Ullmann (1932) is definitely of the opinion that these are separate enzymes. The latter found lichenase in a wide variety of invertebrates thereby confirming the earlier work of Jewell and Lewis (1918) who found it in Porifera, Annelida, Echinodermata, Mollusca, Arthropoda and even in Ascidians though not in any vertebrate. Ullmann concludes that the principal sources of carbohydrate supply in the invertebrates are soluble sugars and the so-called hemicelluloses, the utilisation of cellulose being confined to animals which possess a cellulase. It is to those animals that attention will here be confined.

2. DIGESTION OF CELLULOSE

It was pointed out in the previous article that cellulase is confined to the Protozoa, Mollusca and Arthropoda. Subsequent work has not extended this list.

(a) Protozoa

Rhizopoda.—The work of Lloyd (1926) on *Vampyrella lateritia* which feeds exclusively on the slender *Spirogyra Weberi*, *longata* extends previous work by Cienkowski (1865) on other species of this genus and on *Colpodella pugnax*. *V. lateritia* flattens out on a filament of *Spirogyra*, anchoring pseudopodia extending from the margin of the body. There is then a local application of extruded cellulase which, by digestion of the cell wall, forms an oval opening through which the animal sucks out, with great rapidity, the contents of the plant cell. Lloyd states that, as there is a protein as well as a cellulose membrane to be penetrated, a protease must also be extruded. Stump (1935) has observed *Lesquerensia spiralis*, *Pontigulasia vas*, *P. constricta* and *Diffugia lobostoma* feeding on filamentous green algæ in a manner similar to *Vampyrella*, but by these the plant cell is entered finally through tearing or ripping the cell wall after some initial softening possibly by extruded cellulase. The observations of Rhumbler (1898) and of Stolc (1900) on cellulose digestion in *Amœba verrucosa* and *Pelomyxa palustris* respectively have not been disproved.

Flagellata.—Cleveland (1925, 1928) extended his previous work (see Cleveland (1924, and earlier work there quoted)) on the nutrition of wood-boring termites by describing the ingestion of wood fragments by *Trichonympha campanula*, one of the flagellates found commensal within the gut of such termites. The presence of wood fragments in another such species, *Proboscidiella multinucleata*, has been shown by Kofoed and Swezy (1926) and the mode of ingestion described by Swezy (1923). Trager (1932) has demonstrated the presence of cellulase in extracts made of the hind-gut of the wood-eating roach, *Cryptocercus punctulatus*, which contains great numbers of flagellates in this region. Experiments indicated that the enzyme had its origin in the flagellates. He also got positive results for cellulase with extracts of a culture of *Trichomonas termopsisidis*, an intestinal flagellate from the termite, *Termopsis angusticollis*, as well as from extracts of the gut of this termite and from those obtained from another wood-eating termite, *Reticulitermes flavipes*. Sufficient extract was obtained from the roach for certain of the properties of the enzyme to be determined, including the fact that

cellulose and also cellobiose are broken down to glucose, indicating that two enzymes may actually be present. Further consideration of the results of this work and that of Cleveland will be given in the section dealing with Insecta.

Ciliophora.—The Ophryosolecidæ, a family of Oligotricha found in the gut of various herbivorous mammals—ruminants, some rodents and anthropoids—are capable, according to various authors (see Sandon (1932) for details), of digesting cellulose. On the other hand Becker, Schulz and Emerson (1930), while admitting that cellulose may be ingested, doubt whether it is digested. Margolin (1930) again was able to culture three genera of this family, *Diplo-dinium*, *Entodinium* and *Isotricha*, on pure cellulose but only after this has been previously hydrolysed by bacteria.

(b) *Mollusca*

Gastropoda.—*Pterocera crocata* and *Strombus gigas*, the one an Indo-Pacific species and the other from the Atlantic and both belonging to the family Strombidæ, are the only Prosobranch Gastropoda as yet shown to possess a true cellulase (Yonge, 1932). These animals are inhabitants of shallow water in tropical seas and feed by cropping fine algæ with the jaws. The small, untritured, pieces of weed which are swallowed are broken down in the crop and stomach by a very powerful cellulase which attacks pure cellulose (filter paper) converting it into glucose. The optimum reaction in *Pterocera*, is at pH 5.85. It should also be noted that, according to Oshima (1931), *Halotis* possesses enzymes capable of digesting agar (also alginic acid) contained in the brown algæ on which this animal feeds.

Enriques (1902) originally stated that the herbivorous Opisthobranch, *Aplysia*, possesses a cellulase. Experiments recently carried out in this department by Mr. H. H. Howells have entirely failed to confirm this.

Amongst the Pulmonata cellulase is probably widespread, more so than in any other group in the animal kingdom. The early work of Biedermann and Moritz (1898) Sellière (1906–10), Bierry and Giaja (1908, 1912), Bierry (1914), Alexandrowicz (1913) and Billiard (1914), all on *Helix*, was described in the previous article. Karrer and co-workers have since made exhaustive studies of the cellulase and hemicellulase contained in the digestive fluid of *Helix*. They found that for action on cellulose [Karrer and Illing (1925), Karrer, Schubert and Wehrli (1925), Karrer and Schubert (1926), Schubert (1927), Karrer and Schubert (1927), Faust, Karrer and Schubert (1927)], cotton powder, cotton wool, filter paper and

various types of artificial silk being used as substrates, the digestive juices had to be undiluted or even concentrated. This is probably owing to the limited surface exposed to enzyme action. The properties of the enzyme were also studied, in particular its thermal stability, the kinetics of its action on native cellulose and various kinds of artificial silk, and its purification by adsorption (on an electropositive adsorbant) and dialysis.

More recently Tribby and Carmichael (1935) have identified and studied a cellulase in the slug, *Limax flavus*. They used as a substrate filter paper dissolved in zinc chloride and then precipitated in distilled water, this, after washing, being eventually collected by centrifuging; they also used filings from the endosperm of date seeds. They obtained positive reactions for cellulase in the gut fluid and also in extracts of the digestive diverticula ("liver"), but not from extracts of the stomach or intestine. The pH optimum was about 5.0. Mr. E. T. Embrey, working in this department, has also identified a cellulase in the fluid from the crop and stomach of *Arion ater*, filter paper being employed as the substrate and the optimum pH being about 6.0. This agreed well with the pH of the crop which was found to be 6.05.

Lamellibranchia.—Cellulase is here confined to the wood-boring Tereidinæ (*Teredo* and *Bankia* (*Xylotrya*) but not the less specialised *Xylophaga*). The earlier work of Sigerfoos (1908) and Potts (1923) on the ingestion and intracellular digestion of wood particles in tubules of the digestive diverticula specialised for this purpose has been confined and extended by Lazier (1924) and Yonge (1926), the former in a detailed study of the morphology of the alimentary canal of *Teredo navalis*. In the same way the investigations of Harington (1921) and Dore and Miller (1923) on the cellulase formed within these tubules in *T. navalis* have been amplified by further work on *Bankia setacea* by Miller and Boynton (1926) and Boynton and Miller (1927). They extracted the anterior end of the digestive tract and were able to prove the enzymatic production of glucose from both sawdust and filter paper. There is no cellulase in the crystalline style. Roch (1932) has shown that *T. navalis* can live in wood for a year in the absence of plankton in the surrounding water, but that the presence of abundant plankton does not extend the life of animals removed from their burrows in wood. He concludes that feeding on wood serves not only as a source of the energy required in the act of boring but also is essential for the maintenance and growth of the body.

(c) *Arthropoda*

Crustacea.—It appears more than probable that the cellulase reported in various Decapoda, notably in *Astacus* [Biedermann and Moritz (1898), Bierry and Giaja (1912)], details of which were given in the previous article, is actually a hemicellulase. This was indicated by the nature of the substrates—reserve cellulose from the endosperm of seeds, mannane and mannogalactanes—employed by these workers, and is confirmed by the more recent work of Jewell and Lewis (1918) who found lichenase in *Hemigrapsus nudus* and *Cancer productus* (crabs), *Cambarus virilis* (crayfish), *Upogebia* sp. (burrowing Decapod), and *Pandalus* sp. (prawn), and of Ullmann (1932) who identified a similar enzyme in *Astacus fluviatilis*. Even in the wood boring *Limnoria lignorum* (Isopod) and *Chelura terebrans* (Amphipod) cellulase is absent (Yonge, 1927).

Insecta.—In the previous article it was stated that “no trace of a cellulase has been found in the Insecta (apart from that supplied by the Protozoan symbionts of the Termites)”. That statement no longer stands, cellulase having been identified without doubt in a variety of Insecta. Biedermann (1919) identified this enzyme in a variety of locusts of the family Acridiidae, Bölehrádek (1922) in the salivary secretion of the stick insect, *Dixippus morosus*, and Hering (1926) in the larvæ of *Cemiosoma* (Lepidoptera). Smith (1926) in a study of the feeding methods of various Hemiptera found that penetration of the stylets was probably exclusively mechanical in *Eupteryx auratus* and *Zygina pallidifrons* (Typhlocybidae), *Asterochilton vaporariorum* (Aleyrodidae) and *Myzus persicae*, *M. circumflexus* and *Macrosiphum solanifolii* (Aphididae). On the other hand in *Calocoris bipunctatus* and *Lygus pabulinus* (Capsidae) plant tissues are penetrated mechanically by the stylets but this is “almost certainly assisted by the dissolving effect upon the cell walls of the accompanying salivary secretions.” Further, in *Aspidiotus hederæ* and *Dactylopius longispinus* (Coccidae) the saliva is capable of dissolving cellulose, most markedly in the latter species which by this means penetrates the large xylem vessels with ease.

Falek (1930) working on the larvæ of the wood-boring beetle, *Hylotrupes bajulus*, showed that in the excreta the percentage of cellulose was 12.3 per cent. lower than in the pine wood on which these animals feed. Ripper (1930) tested the stomach contents of a variety of wood-boring insect larvæ for cellulase and also compared the cellulose content of the faeces with that of the original wood. He found no indication of cellulose digestion in *Cossus cossus*, *Dorcus parallelipipedus* and *Osmoderma eremita*, but clear

indications of this in *Cerambyx cerdo* and its probable occurrence in *Xestobium rufovillosum*. Later Mansour and Mansour-Bek (1933, 1934a), working on the larvæ of two cerambycid beetles, *Macrotoma palmata* and *Xystrocera globosa*, were able to reconcile these differences by showing that wood-feeding insects may be divided into two groups. There are those, exemplified by *Xystrocera globosa*, which do not possess a cellulase but derive carbohydrates from the soluble sugars and starch in the wood and so are confined to the sap-wood, and also those, such as *Macrotoma palmata*, which possess cellulase and so penetrate into the heart-wood of trees in which the simpler carbohydrates are largely absent. The latter species possesses, in correlation with this habit, a powerful proventriculus for crushing wood fragments; this organ is absent in *Xystrocera*.¹

The very interesting condition associated with feeding on wood in the larvæ of certain lamellicorn beetles, *Potosia cuprea*, *Oryctes nasicornis*, *Osmoderma eremita* and *Cetonia marmorata*, has been studied by Werner (1926) and Wiedemann (1930). These animals live in rotting wood and the hind-gut is dilated, forming a large proctodæal pouch. There is an abundant intestinal population of both bacteria and flagellates notably in the anterior region of the pouch. The former digest the wood particles taken in and the flagellates, which are unable to do this, digest the bacteria. The medium in the mid-gut and anterior region of the proctodæal pouch is alkaline (due to secretion by the animal), in the hinder region of the pouch acid owing to the action of the bacteria. The protease secreted in the mid-gut is only active in acid media and consequently does not affect the micro-organisms until it reaches the posterior regions of the gut where these are reduced in number. It appears to be well established, therefore, that these insects feed on flagellates and bacteria, the latter only having digested wood.

In the opinion of Mansour and Mansour-Bek (1934a and b), a similar explanation is applicable to the wood-boring termites. They think this more probable than Cleveland's statement that the flagellates (shown to ingest and digest wood as already reported in this paper) pass on a part of the products of cellulose digestion to the termite. Further, they point to certain experiments of Cleveland which indicate that some termites may live longer than others in the absence of their intestinal flagellates and they suggest that wood-eating termites may also be found to be divided into two

¹ More recently Mansour and Mansour-Bek (1937) have demonstrated the presence of cellulase in the gut of the larvæ of the wood-boring beetle, *Stromatium fulvum*. True cellulose, lichenin and lignocellulose were all attacked, the respective pH optima being at 5.6, 5.5 and 5.5.

groups, those without cellulase which feed on the contained flagellates and those with cellulase which feed directly on wood. Holdaway (1933) has shown that the termite which causes the greatest damage to timber in Australia is free from flagellates and it may therefore be assumed to possess a cellulase.

The work of Buchner (1930) and his school on the significance of the symbiotic micro-organisms of various kinds—bacteria, yeasts and protozoa—in and around the gut of wood-eating insects is critically examined by Mansour and Mansour-Bek (1934b). They point, with justice, to the lack of experimental evidence for the conclusion of Buchner that these organisms are concerned with the digestion of wood, and are unable to agree with this.

We are left, therefore, with the general conclusion that certain highly specialised wood-eating insects are able to digest cellulose, others harbour micro-organisms which feed, directly or indirectly on wood, and others again, which live only in sap-wood, feed on the simpler carbohydrates present in this region.

3. DIGESTION OF CHITIN

Chitin, which is an amino-polysaccharide consisting largely of glucosamine units, the amino groups of which are acetylated, forms the exoskeleton of many invertebrates, notably the Arthropoda; it also constitutes the cell wall of Fungi. An enzyme capable of digesting chitin has been identified in *Helix* (Karrer and Hofmann (1929), Karrer and François (1929)). This chitinase has a pH optimum at 5.2 and converts chitin into N-acetylglucosamine with traces of glucosamine. Experiments by Mr. E. T. Embrey (see above) on the slug, *Arion ater*, have revealed the presence of a chitinase with an optimum about pH 6.0, appreciable quantities of glucose being formed. This enzyme may safely be assumed to be concerned in nature with the disintegration of the cell walls of the fungi which form the chief food of many land Pulmonata.

In the Arthropoda, chitinase has been found by Schulze (1927) in the beetle, *Platydemus tricuspidis*, which feeds on fungi, and also by Ramme (1920) in the larvæ of the ectoparasitic hymenopteran, *Pseudagenia carbonaria*, which feeds on spiders. In the latter the enzyme is extruded from the mouth and is employed in the extra-intestinal digestion of the integument of the host spider.

4. DISCUSSION

Considering this record of work on the presence of cellulase and chitinase amongst the invertebrates in its biological implications we arrive at the conclusion that the presence of these enzymes

constitutes an important physiological adaptation. But the infrequency with which these enzymes are encountered also indicates the difficulty their evolution entails. They would seem only to appear as "a last resort" in animals which are highly adapted in other ways to a life in wood or a diet consisting largely of this substance. For instance, whereas *Teredo* and *Bankia* possess cellulase, this enzyme and also the specialised digestive diverticula in which it is formed are absent in *Xylophaga dorsalis* which is equally confined to life in wood and has the shell equally adapted as a boring organ and the foot as a sucker-like attachment.

It is also clear that the possession of a cellulase may be for one of two purposes—for the penetration only of woody tissues, i.e. as an aid to, or alternative for, mechanical entry, or for the direct conversion of cellulose into glucose for purposes of nutrition. Thus in the Rhizopoda extruded cellulase apparently only assists mechanical penetration of the cell walls of plants in *Lesquerensia*, *Pontigulasia* and *Diffugia*, but is the sole agent for this purpose in *Vampyrella*. In the Hemiptera examined by Smith, there is a nice gradation from purely mechanical penetration in Typhlocybidae, Aleyrodidae and Aphididae, to assistance by cellulase in Capsidae and still more so in Coccidae. In the Strombidae also the cellulase may be concerned primarily with the breakdown of the cell walls, which are certainly not mechanically ruptured to any extent by the essentially cropping jaws. At the same time the glucose so formed will undoubtedly assist in the nutrition of these gastropods. *Pseudagenia* certainly uses its chitinase essentially for penetration.

On the other hand wood particles undoubtedly form the principal food of the intestinal flagellates of wood-eating termites and of the roach, *Cryptocercus*. Both *Teredo* and *Bankia* rely on cellulose to provide necessary carbohydrates, as do insects such as *Macrotoma*, boring into the heart-wood of trees. It is less easy to be certain as to the exact significance of the cellulase in *Helix* and in the slugs, *Limax* and *Arion* (or of chitinase in the beetle, *Platydema*). By its action the cell contents will certainly be more fully exposed to the action of other digestive enzymes while additional glucose will be formed. The same applies to the chitinase possessed by these gastropods. It is certainly true to say that the possession of both these enzymes, enabling their possessors to utilise to the full both plant and fungal food, has had an important bearing on the success of these land pulmonates, a fact sufficiently indicated by their abundance and ubiquity.

The utilisation, by certain larval longicorn beetles, of bacteria

as the agents of cellulose digestion is reminiscent of conditions in certain herbivorous mammals. But the insertion into the food chain of flagellates, and the direct utilisation of these in termites, has up to the present been found only in the Insecta.

REFERENCES

- ALEXANDROWICZ, J. S. *Arch. ges. Physiol.*, CL, 57, 1913.
 BECKER, E. R., SCHULZ, J. A., and EMERSON, M. A. *Iowa State Coll. J. Sci.*, IV, 215, 1930.
 BÉLEHRÁDEK, J. *Arch. Intern. Physiol.*, XVII, 260, 1922.
 BIEDERMANN, W. *Arch. ges. Physiol.*, CLXXIV, 392, 1919.
 — and MORITZ, P. *Arch. ges. Physiol.*, LXXIII, 219, 1898.
 BERRY, H. *C.R. Soc. Biol., Paris*, LXXVI, 710, 1914.
 — and GIAJA, J. *C.R. Acad. Sci., Paris*, CXLVII, 268, 1908.
 — — *Biochem. Zeit.*, XL, 370, 1912.
 BILLIARD, G. *C.R. Soc. Biol., Paris*, LXXVI, 566, 1914.
 BOYNTON, L. C. and MILLER, R. C. *J. Bio. Chem.*, LXXV, 613, 1927.
 BUCHNER, P. *Tier und Pflanze in Symbiose*. Berlin, 1930.
 CIENKOWSKI, L. *Arch. mikr. Anat.*, I, 203, 1865.
 CLEVELAND, L. R. *Biol. Bull.*, XLVI, 177, 1924.
 — *Biol. Bull.*, XLVIII, 282, 1925.
 — *Biol. Bull.*, LIV, 231, 1928.
 DORE, W. H. and MILLER, R. C. *Univ. Calif. Publ. Zool.*, XXII, 383, 1923.
 ENRIQUES, P. *Mitt. Zool. Sta. Neapel*, XV, 281, 1902.
 FALCK, R. *Cellulosechemie*, XI, 89, 1930.
 FAUST, O., KARRER, P., and SCHUBERT, P. *Helvet. Chim. Acta*, XI, 231, 1927.
 HAAS, P., and HILL, T. G. *An Introduction to the Chemistry of Plant Products*, Vol. I, 4th edition. London, 1928.
 HARRINGTON, C. R. *Biochem. J.*, XV, 736, 1921.
 HERING, M. *Biologie der Schmetterlinge*. Berlin, 1926.
 HOLDAWAY, F. G. *J. Council Sci. Ind. Research Australia*, Aug. 1933.
 JEWELL, M. E. and LEWIS, H. B. *J. Biol. Chem.*, XXXIII, 161, 1918.
 KARRER, P., and FRANÇOIS, G. v. *Helvet. Chim. Acta*, XII, 986, 1929.
 — and HOFMANN, A. *Helvet. Chim. Acta*, XII, 616, 1929.
 — and ILLING, H. *Helvet. Chim. Acta*, VIII, 245, 1925.
 — and LIEB, H. *Helvet. Chim. Acta*, VIII, 248, 1925.
 — and SCHUBERT, P. *Helvet. Chim. Acta*, IX, 893, 1926.
 — — *Helvet. Chim. Acta*, XI, 229, 1928.
 — — and WEHRLI, W. *Helvet. Chim. Acta*, VIII, 797, 1925.
 KEMMER, N. A. *Entom. Tidskr.*, XLVII, 65, 1928.
 KOFOID, C. A., and SWEZY, O. *Univ. Calif. Publ. Zool.*, XXVIII, 301, 1926.
 LAZIER, E. L. *Univ. Calif. Publ. Zool.*, XXII, 455, 1924.
 LLOYD, F. E. *Michigan Acad. Sci. Arts Letters*, VII, 395, 1926.
 MANSOUR, K., and MANSOUR-BEK, J. J. *Proc. Kon. Akad. Wet. Amst.*, XXXVI, 795, 1933.
 — *J. Exp. Biol.*, XI, 243, 1934a.
 — *Biol. Rev.*, IX, 363, 1934b.
 — *Enzymologia*, IV, 1, 1937.

- MARGOLIN, S. *Biol. Bull.*, LIX, 301, 1930.
- MILLER, R. C., and BOYNTON, L. C. *Science*, LXIII, 1638, 1926.
- OSHIMA, K. *Bull. Agric. Chem. Soc., Japan* (quoted Vonk), 1931.
- POTTS, F. A. *Proc. Camb. Phil. Soc., Biol. Sci.*, I, 1, 1923.
- RAMME, W. *Sitz. Ges. Naturf. Berlin*, 1920, 130.
- RHUMBLER, L. *Arch. Entw.-Mech.*, VII, 104, 1898.
- RIPPER, W. *Zeit. vergl. Physiol.*, XIII, 314, 1930.
- ROCH, F. *Ark. Zool.*, XXIVa, Nr. 5, 1932.
- SANDON, H. *Publ. Fac. Sci. Egypt. Univ., Cairo*, No. 1, 1932.
- SCHUBERT, P. *Inaug.-Dissert.*, Zürich, 1927.
- SCHULZE, P. *Zeit. Morph. Ökol. Tiere*, IX, 333, 1927.
- SELLIÈRE, G. *C.R. Soc. Biol., Paris*, LXI, 205, 1906.
- *C.R. Soc. Biol., Paris*, LXIII, 515, 1907.
- *C.R. Soc. Biol., Paris*, LXVIII, 107, 1910.
- SIGERFOOS, C. P. *Bull. U.S. Bur. Fish.*, XXVII, 191, 1908.
- SMITH, K. M. *Ann. Appl. Biol.*, XIII, 109, 1926.
- STOLC, A. *Zeit. wiss. Zool.*, LXVIII, 1900.
- STUMP, A. B. *Biol. Bull.*, LXIX, 136, 1935.
- SWEZY, O. *Univ. Calif. Publ. Zool.*, XX, 391, 1923.
- TRAGER, W. *Biochem. J.*, XXVI, 1762, 1932.
- TRIBBY, W. W., and CARMICHAEL, E. B. *Proc. Soc. Exp. Biol. Med.*, XXXIII, 42, 1935.
- ULLMANN, T. *Zeit. vergl. Physiol.*, XVII, 520, 1932.
- VONK, H. J. *Biol. Rev.*, XII, 245, 1937.
- WERNER, E. *Zeit. Morph. Ökol. Tiere*, VI, 150, 1926.
- WIEDEMANN, J. F. *Zeit. Morph. Ökol. Tiere*, XIX, 228, 1931.
- YONGE, C. M. *SCIENCE PROGRESS*, XX, 242, 1925.
- *Trans. Roy. Soc. Edinb.*, LIV, 703, 1926.
- *Nature*, CXIX, 855, 1927.
- *Sci. Rpt. G. Barrier Reef Exped., Brit. Mus. (Nat. Hist.)*, I, 259, 1932.

THE CONDUCTION OF ELECTRICITY IN POLAR CRYSTALS

By N. F. MOTT, M.A., F.R.S.

Melville Wills Professor of Theoretical Physics in the University of Bristol

THE discovery of quantum mechanics has led to the formulation of a fairly complete theory of conduction of electricity in metals; perhaps less attention has been paid to conduction in non-metals, partly owing to very great complexity of the phenomena which are observed. In the present article we shall attempt to summarise from the theoretical side the present state of our knowledge of the latter field of research. The subject is a wide one, and includes the insulating properties of dielectrics and their breakdown under high stress, photoconductivity, the absorption of light by non-metals and the photochemistry of solids, ionic conduction in polar crystals and the behaviour of semi-conductors and of certain classes of luminescent materials.

We may take sodium chloride as an example of a non-conducting polar salt. According to modern ideas, crystals of this salt normally do not conduct because they are built up of ions in which the electrons form closed shells; both the chlorine negative ion and the sodium positive ion have the rare gas configuration in which the outermost electronic shell contains eight electrons, which is the maximum number allowed by the Pauli principle. An electron cannot wander, for instance, from one chlorine ion to its neighbour because the possible places for an electron in that neighbour are all already occupied. For the further development of these ideas the reader is referred either to the original paper on the subject due to Wilson [1], or to the various text-books on the theory of metals [2, 3, 4, 5].

If we wished to introduce an *extra* electron into a sodium chloride lattice, we should have to put it on to one of the sodium ions, and thus form a sodium atom in the middle of the crystal. Now the orbit ¹ of an electron in a sodium atom is rather larger than the interatomic distance in the crystal, so that the sodium "atom"

¹ Or, in terms of wave mechanics, the radial extension of the wave function.

is very much disturbed by its neighbours. Calculations [6] show that the electron can jump quite freely from one sodium ion to the next and so on through the crystal; it is, in fact, just as free as a free electron in a metal. Fröhlich [7] has made an estimation of its mean free path, and finds this to be some hundred interatomic distances if the electron is moving with several electron volts energy, though if it has thermal energies only the mean free path drops to the order ¹ of 10^{-7} cm.

An extra electron in a polar crystal can, then, have any energy above a certain minimum. This band of allowed energy levels is often referred to as the conduction band. The energy $-\chi$ of the lowest conduction level has been estimated accurately only for the alkali halides [8]; it is for sodium chloride about -0.5 e.V. That

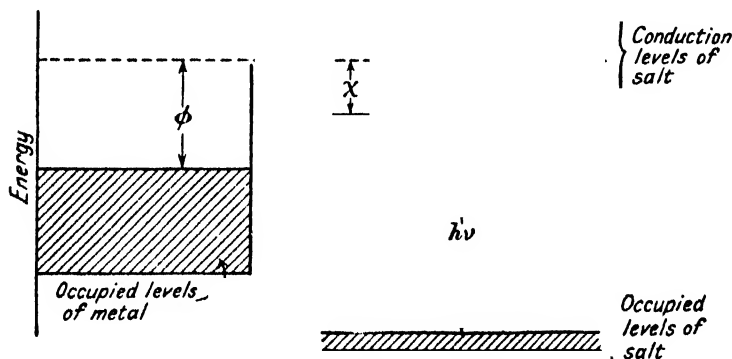


FIG. 1.—Energy levels in an insulating crystal and metal in contact. The dotted line represents the zero of energy, i.e. the energy of an electron at rest in free space.

is to say, an amount of work equal to $+0.5$ e.V must be done to remove from the crystal an electron in the lowest conduction level. The conduction levels in salts of high dielectric constant, such as AgBr, are probably lower.

We can now see why, when a dielectric is placed in contact with metal electrodes, electrons do not pass from the metal into the conduction level of the salt. If the work function ϕ of the metal is greater than χ , work equal to $(\phi - \chi)$ will have to be done to remove an electron from the metal into the conduction band of the salt, as shown in Fig. 1. The state of affairs at the boundary between the metal and salt is thus similar to that between a metal and a vacuum. The writer does not know if ϕ is ever less than χ , nor what would happen in this case.

This is in agreement with experiments by Engelhard [34] on Cu_2O .

Small steady currents may be obtained in insulators under high fields (*cf.* for instance, von Hippel [9]). Zener [10] has shown that under high field strengths in, for instance, NaCl, electrons will now and then be pulled out of the chlorine ions into the conduction band.¹ The small currents observed by von Hippel may be due to this cause. They may, on the other hand, be due to cold emission from the electrodes; in this case the current obtained should depend on the work function ϕ of the metal used for the electrodes and on contamination of the metal-crystal boundary. It would be interesting to investigate this point.

Under sufficiently high field strengths dielectrics break down. A quantitative theory of the breakdown has recently been given by Fröhlich [7]. Fröhlich considers the behaviour of any stray

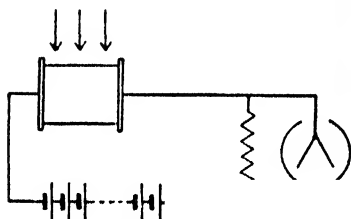


FIG. 2.—Experimental set-up for measuring photoconductivity.

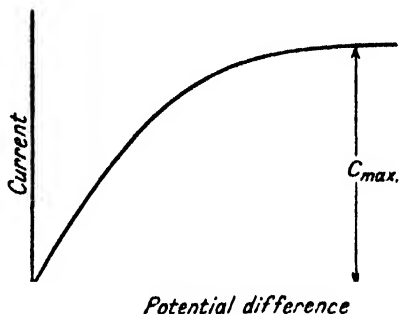


FIG. 3.—Primary photoelectric current as a function of the potential difference across the electrodes.

free electrons in the material, and enquires whether they will gain energy from the external field more rapidly than they lose it as heat to the crystal. He finds that for sufficiently strong fields this is the case, so that each stray electron is accelerated until it produces secondaries, which in their turn are accelerated so that an "electron avalanche" is formed. Fröhlich obtains a formula for the breakdown strength, which is in excellent agreement with experiment for a number of materials. A consequence of the theory is that a mixed crystal of, for instance, two alkali-halides has a higher breakdown strength than the pure crystals, because the mean free path of an electron is shorter in a mixed crystal (as shown by the high resistance of metallic alloys), and so the electron loses energy to the crystal more readily.

The phenomenon of photoconductivity is an illustration of the

¹ In Zener's paper dielectric breakdown is ascribed to a process of this kind; we prefer, however, the theory due to Fröhlich mentioned above.

existence of conduction levels in insulators. If an ion of the crystal absorbs a quantum of light, an electron may make a transition from the bound state in the ion into the conduction band of levels, where it is free to move in an applied field.

Gudden, Pohl and their co-workers have made experiments in which a crystal is mounted between two electrodes, as shown in Fig. 2, and illuminated for a short period of time only, thus avoiding the setting up of space charges. The type of current-voltage curve obtained for zinc-blende [11], silver bromide [12] and for diamond [13, 14] is shown in Fig. 3; for the alkali-halides it was impossible to obtain saturation.

For fields giving saturation, the current passing through the electrometer was found to be approximately equal to $\frac{1}{2}Ned$, where N was the number of light quanta absorbed by the crystal, d the distance between the electrodes, and e the electronic charge. This suggests that every quantum of light absorbed releases an electron, which is pulled right out of the crystal; the *mean* distance to the anode from the point where a quantum is absorbed will be $\frac{1}{2}d$, if the crystal is uniformly illuminated.

For fields which do not give saturation, it is clear that the electrons must come to rest in some stable position before reaching the anode. The electrons certainly do not usually recombine with the ions from which they have been ejected; for if this were the case the mean distance travelled by an electron, as well as the number of electrons produced, would depend on the intensity of the light. It is easy to show that the current would then be proportional to the square root of the intensity of the light, instead of to the intensity, as observed.

It is generally assumed that the electrons are trapped in the neighbourhood of cracks or impurities, where positions of specially low potential energy may be expected to exist [15, 16]; for alkali-halides quite a definite model for these special positions will be described below. One would expect the probability that an electron will be trapped while crossing a crack to be much less than unity, so the range will in any case be proportional to the field. At high temperatures these special positions are not stable, as shown by the fact that a photocurrent in alkali-halide crystals continues after the illumination is cut off, if the temperature is not too low.

Reimann [17] has investigated the decay in the conductivity of a zinc-blende crystal *after* illumination; he believes the decay to be due to electrons going back to their original positions after being released from their trapped positions by thermal agitation. If n is the number of electrons in excited positions, then the number of

places to which they can return is also equal to n , so that the rate of change of n is given by

$$\frac{dn}{dt} = -An^2$$

where A depends on the temperature. The solution is

$$n = \frac{A}{t + \text{const.}}$$

so we expect the conductivity, which will be proportional to n , to decay inversely as the time; this is in agreement with Reimann's observations.

We must now discuss in greater detail the mechanism of light absorption by a crystal. We show in Fig. 4 the ultra violet absorption spectrum of sodium chloride, recently measured by Schneider and O'Bryan [18]. The two peaks are to be interpreted as follows [8]:

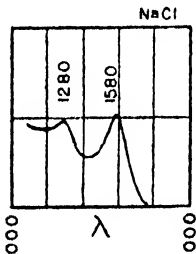


FIG. 4.—Absorption spectrum of thin films of NaCl.

A diagram such as Fig. 1 would suggest that the absorption of a quantum of light by a crystal must necessarily eject an electron into the conduction band. In this respect, however, the diagram is misleading, as first pointed out by Peierls [19] and further emphasised by Frenkel [20]. If an electron is ejected from an ion of the crystal, it will leave behind it a "hole," or excess positive charge, and at a distance r

from this hole there will be an electric field $e/\kappa r^2$, where κ is the dielectric constant of the crystal. This field acts on the electron in the same way as the field of the proton acts on the electron in a hydrogen atom. As a consequence, there are in the field of the "hole" a series of stationary states leading up to a series limit. Ideally, therefore, the absorption spectrum of an insulator consists of a series of sharp lines leading up to a series limit, beyond which continuous absorption sets in. In any real crystal the lines will be very much broadened by the vibrations of the atoms. In Fig. 4, the peak at 1580 Å. is the first absorption line; the other lines are unresolved and the peak at 1280 Å. corresponds to the series limit; beyond this true continuous absorption sets in. Similar measurements for KI [21] show that at low temperatures the first peak becomes sharper, though even at the absolute zero the "zero-point" vibrations should lead to some broadening.

The electronic transition to which the first peak is due may be described in a different way, which is however practically equivalent to the foregoing description. One can say that the electron is

ejected from a chlorine ion to an adjacent sodium ion. On the basis of this model de Boer [22] and von Hippel [23] have estimated the energy of the transition and hence the wave-length of the line. For wave-lengths shorter than that of the second peak the electron is removed to a distant metal ion.

In pure NaCl, then, a wave-length less than 1280 Å. will be necessary to free an electron and so cause photoconductivity. Actually no photoconductivity at all is observed when alkali-halides are illuminated in their characteristic absorption bands; but this is probably because, owing to the high absorption coefficient, the light penetrates only a distance of about 10^{-6} cm. It is, however, in agreement with our considerations above that no photoconductivity is observed [24] when a crystal is illuminated in the long wave-length tail of the absorption band, where the absorption coefficient is quite small and the light can penetrate several mm. Experiments on photo-currents in alkali-halides have been carried out mainly with crystals coloured by the presence of excess alkali-metal (see below).

Photoconductivity is, however, observed in zinc-sulphide, silver-bromide and other salts, containing no impurities deliberately introduced. The absorption spectra of these salts do not show any strongly marked maxima; it is not certain whether, for the wave-lengths used, the absorption is due to atoms of the perfect crystal, to atoms at impurities, or to atoms situated at the surfaces of cracks, which, according to Herzfeld [16], absorb for longer wave-lengths.

In either case, the argument given above is valid, that at any rate at the long wave-length end of the absorption spectrum the electron is only raised to an excited state, but *not* ejected directly into the conduction band. Since photoconductivity is nevertheless observed in many salts near the long wave limit of the absorption band, the present author has suggested [25] that thermal agitation is sufficient to free the electron before it falls back to its normal state. In this case a drop in the photocurrent is to be expected as the temperature is lowered. A very marked drop is in fact found [26] in coloured rock salt at -150° C., and also in ZnS [27]. No drop, however, appears in AgBr [12] down to liquid air temperatures; further experimental investigation of this point would be of value.

We must now turn to a more detailed investigation of the influence of lattice imperfections on conduction in crystals. According to Schottky [28], Jost [29], and others, in a polar crystal in thermal equilibrium at a sufficiently high temperature, a number of lattice points of either sign are unoccupied by the corresponding ions.

As the temperature is raised these "holes" are formed at the surface and travel inwards; they form in the crystal a kind of gas, moving about with thermal energies. The authors quoted ascribe the electrolytic conductivity shown by solid salts at high temperatures to the presence and motion of these holes. Moreover, since these holes are only mobile at high temperatures, it is clear that any

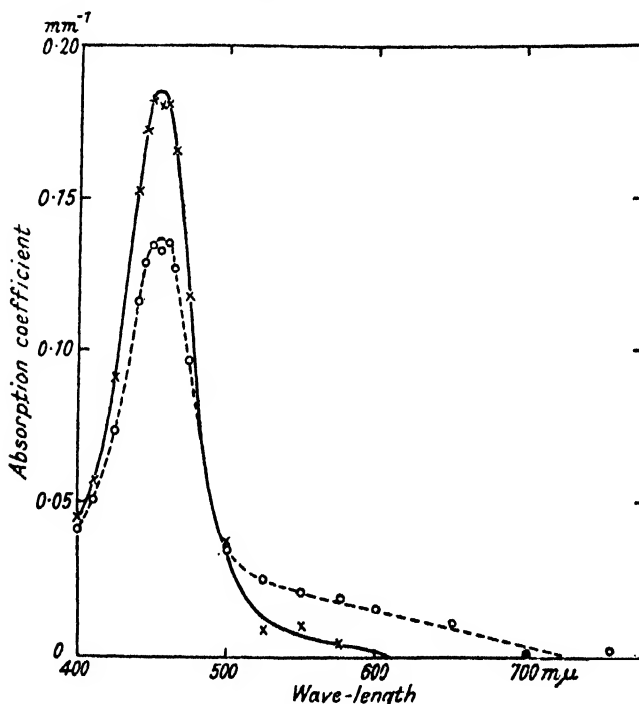


FIG. 5.—Absorption spectrum of sodium-chloride crystal with F-centres. The dotted line shows the change in the shape of the band on illumination, due to the superposition of the F' band on the original F-band.

crystal formed from the melt will contain at low temperatures a number of these holes "frozen in."

The yellow colour of rock salt that has been exposed to X-rays is well known. All alkali-halides can be coloured in this way, and give a characteristic absorption band (Fig. 5), known as the F-band.¹ De Boer [30] has proposed the following hypothesis about the nature of the F-band; he suggests that it is due to electrons trapped at lattice points where negative ions are missing; we have seen that in any real crystal a number of such points will exist. Since a field e/xr^2 exists at a distance r from a vacant negative lattice

¹ From the German "Farbe," colour.

point, it is clear that electrons will be attracted to these points and can be trapped there. The absorption band shown in Fig. 5 is then due to the absorption of light by these trapped electrons.

When a crystal is irradiated with X-rays, electrons are released from the lower levels of the atoms or ions, and move at random in the conduction band until they either recombine with their original ions, or are trapped at a point where a negative ion is missing, forming F-centres. In the latter case they may eventually escape and return to their original ions; we account thus for the fading of crystals coloured by X-rays.

Pohl and his co-workers [26] have found that alkali-halide crystals become coloured when heated in alkali metal vapour; the crystal then acquires a stoichiometric excess of alkali metal, but the absorption band is identical with that obtained by irradiating the crystal with X-rays. In this case holes must be formed at the surface and collect an electron from a metal atom; the F-centre then diffuses into the crystal, while the anion and cation so liberated adhere to the surface of the crystal.

Space will not allow an enumeration of the observed properties of F-centres,¹ many of which can be explained in terms of this model. It is, however, worth mentioning that in work on photoconductivity in coloured alkali-halides, Pohl finds that the current per absorbed quantum, and hence the range that an electron moves before it is trapped, is inversely proportional to the number of F-centres present. He deduces that electrons are trapped by the F-centres; in terms of our model, it follows that *two* electrons can be trapped by the field round a vacant negative lattice point, just as two electrons can be "trapped" by a proton to form H^- . The process is accompanied, as we should expect, by a shift of the absorption band towards the red. It is thus very satisfactory that for the alkali-halides we have a detailed picture of the trapping mechanism which limits the photoelectric current, and do not have to appeal to the vague hypothesis of cracks.

If the crystal contains colloidal particles of metal (as do natural crystals of blue rock salt), the range of the electrons is still further cut down; particles of metal act as very efficient traps. On the basis of this fact Gurney and Mott [31] have given a theory of the photolysis of silver bromide (the print-out effect in photographic emulsions). In a crystal already containing small particles of metallic silver, electrons released by the light will normally be trapped by a metal particle; so that for every quantum absorbed one electron is added to the metal. Silver bromide is an ionic

¹ Cf. ref. 26.

conductor at room temperature; the colloidal silver specks will discharge by attracting the positively charged silver ions, which move up and adhere to them. Thus the silver specks grow as the light is absorbed.

The study of photoconductivity is of value for understanding the action of luminescent materials. These may be divided into two classes. One, of which the uranyl salts are an example, shows no photoconductivity; thus the ions or atoms within the crystal which absorb the light do not lose an electron in the process, but are merely raised to an excited state. This class will not concern us here. To the other class belong the zinc-sulphide phosphors sensitised by heavy metals, in which the absorption of light is associated with photoconductivity; these also show phosphorescence, or, in other words, a gradual re-emission of light lasting for many seconds after the exciting radiation is cut off.

For this latter class we can understand fairly well how the light is re-emitted, and make some predictions about the dependence of phosphorescence on temperature.

The light is absorbed by atoms of the heavy metal, probably present in solid solution. From an atom of the heavy metal an electron is ejected into the conduction band of the zinc-sulphide crystal. Here it wanders round until it is trapped at one of the metastable levels existing at impurities or cracks. But, as we have seen, at not too low a temperature these positions are not stable; every now and then the thermal agitation of the surrounding atoms will free the electron again. Thus eventually it will find one of the ionised heavy metal atoms and recombine with it, emitting radiation.

As we have seen, such a mechanism implies that the number of electrons in the conduction band decays inversely as the time. Since the intensity I of radiation emitted by the crystal will be proportional to the product of the numbers of electrons and of vacant places, it follows that after the exciting radiation is shut off I decays according to the law

$$I = \frac{A}{(t + \text{const.})^2}$$

According to a note by Reimann [17], this is in agreement with experimental observations by Antonow-Romanowski [32].

The constant A , giving the rate of decay, will increase rapidly as the temperature is raised. At sufficiently low temperatures the positions at cracks may be quite stable, and so A will be practically zero. This is in agreement with experiment [33]; very little

luminescence is shown at low temperatures. Another factor which may contribute to the same effect is the fall, as the temperature is lowered, in the number of electrons liberated per absorbed quantum, which has been already discussed in this article.

At sufficiently high temperatures also a fall in the intensity of the re-emitted radiation is to be expected. When an electron in the conduction band meets an ionised heavy metal atom and recombines with it, it can give up its energy either as radiation, or as heat; in the latter case the surrounding atoms will be set into vibration. According to calculations by Peierls [19] based on quantum mechanics, the latter process becomes very much more probable as the temperature is raised, because the electron is then more disturbed by the surrounding atoms and more able to communicate energy to them. Recent experiments by Randall [33] show that a drop in the intensity of emitted radiation is in fact observed as the temperature is raised.

Finally, a few words may be said about the present state of the theory of semi-conductors; by this term we mean substances showing electronic conduction, with a conductivity which increases as the temperature is raised. According to the theory given some years ago by Wilson [1], such substances contain special electronic levels in the neighbourhood of impurities; and from these levels electrons are liberated into the conduction band as the temperature is raised. If E is the work required to liberate an electron, the number of electrons in the conduction band and hence the conductivity is proportional to $e^{-E/2kT}$. One would *not*, however, expect E to be equal to the work necessary to free an electron optically, as frequently stated in the literature. After an electron is freed, the surrounding ions will move into new positions of equilibrium in the field of the "positive hole" left by the electron, and energy will be released. In calculating the conductivity, which depends on the number of electrons on the conduction band in a crystal *in thermal equilibrium*, we must of course take E to be the total energy, including that released by the ions, but by the Franck-Condon principle, in an optical transition the mass-centres do not have time to move until the process is over. If μ is the low-frequency limit of the photo current-frequency curve of the crystal,¹ we should expect $h\mu$ always to be *greater* than E .

Alkali-halide crystals with F-centres form an elegant illustration of Wilson's theory of semi-conductors, the special places where electrons are trapped being the lattice points with missing negative

¹ In practice practically equal to or slightly less than the low-frequency limit of the absorption band, as we have seen above.

ions discussed above. At the temperatures ($\sim 600^\circ \text{C.}$) at which electrons begin to be released, the crystals are already good ionic conductors and the motion of the electrons in an applied field can only be detected by the motion of the coloured region in partly coloured crystals. An experiment to show this is illustrated in Fig. 6; the boundary between the coloured region is found [26] to move with a velocity which varies with the temperature as $e^{-A/T}$, where A is a constant. Moreover, the energy $2KA$ is less than the optical excitation energy of an F-centre (for KCl they are 2.0 and 2.3 e.V. respectively).

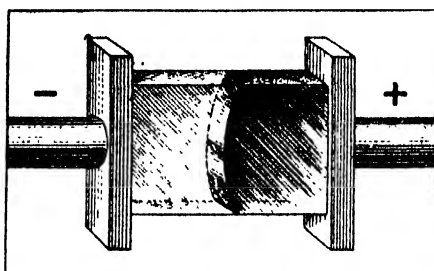


Fig. 6.—Behaviour of a coloured alkali-halide crystal at about 600°C. in an applied field; the boundary between the coloured and transparent parts moves across the crystal.

Copper oxide (Cu_2O) heated under pressure in oxygen is a semiconductor which has recently been discussed in some detail. The salt contains a stoichiometric excess of oxygen; it is believed that some of the lattice points normally occupied by copper ions are vacant. Measurements of the Hall coefficient¹ [34] show that the current is carried by positive charges; thus we imagine that there exist a few Cu^{++} ions among the Cu^+ ions of the lattice, and the "positive hole," or place where an electron is missing, can travel through the crystal. At low temperatures these "positive holes" are trapped in the neighbourhood of a missing copper ion; the analogy with de Boer's model of the F-centres is obvious. Only at higher temperatures are a few "holes" released, so that a current is possible.

¹ If a magnetic field is applied at right angles to a wire carrying a current, an electromotive force is induced in the direction perpendicular to both. The ratio of this e.m.f. to the product of current and field is known as the Hall coefficient. Elementary theoretical considerations show that the sign of the Hall coefficient depends on whether the current is carried by positive or negative charges. (Cf. ref. 3, Chapter VII.)

REFERENCES

1. A. H. WILSON, *Proc. Roy. Soc., A*, **134**, 277 (1931).
2. A. SOMMERFELD and H. BETHE, *Hand. d. Phys.*, **23/2** (1933).
3. N. F. MOTT and H. JONES, *The Theory of the Properties of Metals and Alloys*, Oxford, 1936.
4. A. H. WILSON, *The Theory of Metals*, Cambridge, 1936.
5. H. FRÖHLICH, *Electronentheorie der Metalle*, Leipzig, 1936.
6. S. R. TIBBS, *Trans. Far. Soc.* (to be published).
7. H. FRÖHLICH, *Proc. Roy. Soc., A*, **160**, 230 (1937).
8. N. F. MOTT, *Trans. Far. Soc.* (in press).
9. A. VON HIPPEL, *Ergebn. d. exakt. Naturw.*, **14**, 115 (1935).
10. C. ZENER, *Proc. Roy. Soc., A*, **145**, 521 (1934).
11. A. L. HUGHES and L. A. DU BRIDGE, *Photoelectric Phenomena*, Chapter VIII, 1932.
12. W. LEHFELDT, *Nachr. d. Gesellsch. d. Wiss. zu Göttingen*, **1**, 170 (1935).
13. B. GUDDEN and R. W. POHL, *Z. Phys.*, **17**, 331 (1923).
14. R. ROBERTSON, J. J. FOX and A. E. MARTIN, *Proc. Roy. Soc., A*, **157**, 579 (1936).
15. I. TAMM, *Z. Phys.*, **76**, 849 (1932).
16. K. HERZFELD, *Z. phys. Chem.*, **105**, 329 (1923).
17. A. L. REIMANN, *Nature*, **140**, 501 (1937).
18. E. G. SCHNEIDER and H. M. O'BRYAN, *Phys. Rev.*, **51**, 293 (1937).
19. R. PIERLS, *Ann. d. Phys.*, **13**, 905 (1932).
20. J. FRENKEL, *Phys. Z. Sowjet*, **9**, 158 (1936).
21. H. FESEFELDT, *Z. Phys.*, **64**, 626 (1930).
22. J. H. DE BOER, *Electron Emission and Adsorption Phenomena*, Cambridge, 1935.
23. A. VON HIPPEL, *Z. Phys.*, **101**, 680 (1936).
24. A. SMAKULA, *Z. Phys.*, **63**, 762 (1930).
25. N. F. MOTT, *Proc. Phys. Soc.* (in press).
26. R. W. POHL, *Proc. Phys. Soc.*, **49**, extra part, 3 (1937).
27. A. L. REIMANN (unpublished).
28. W. SCHOTTKY, *Z. phys. Chem., B*, **29**, 335 (1935).
29. W. JOST, *Chemische Reaktion in festen Stoffen*, Dresden, 1937.
30. J. H. DE BOER, *Rec. Trav. Chim. Pays-Bas*, **56**, 301 (1937).
31. R. W. GURNEY and N. F. MOTT, *Proc. Roy. Soc., A*, **164**, 151 (1938).
32. W. W. ANTONOW-ROMANOWSKI, *Phys. Z. Sowjet*, **7**, 366 (1935).
33. J. T. RANDALL, *Proc. Phys. Soc.*, **49**, extra part, 46 (1937).
34. E. ENGELHARD, *Ann. d. Physik*, **17**, 540 (1932).

THE PHYSICAL BASIS OF SOIL STRUCTURE

BY E. W. RUSSELL, M.A., PH.D.

Rothamsted Experimental Station, Harpenden

It is a matter of everyday observation that each kind of plant grows better in some soils than in others, and in soils cultivated in some ways than in those cultivated in others. An important factor controlling the suitability of a soil for a particular plant is its structure, which is the arrangement of the soil particles, or of the spaces between them, in the soil. A fundamental problem in Soil Physics is the devising of methods to describe the structure of the soil in terms of quantities which are known to control the plant growth. The lines along which the description should be made are now probably known but it is not yet known how much of the necessary quantitative information the present experimental methods can give.

Plants only thrive under certain soil conditions which, for the present discussion, can be divided into five classes, namely a proper supply of nutrients, an absence of toxic substances, a good water supply, a good air supply and a stable medium in which to grow. The first two conditions need not be considered here, except to note that toxic substances may be produced in the soil in the absence of sufficient oxygen, but they are usually oxidised or decomposed to harmless ones if an adequate oxygen supply can be introduced.

The last condition, that the soil should be reasonably stable, is of obvious importance. No agricultural crop can survive if the soil in which it is growing is blown away by the wind or washed away by rain. But the two conditions which are directly dependent on the soil structure are the air and water supply.

The roots of most plants need a continuous supply of water and oxygen, and a continuous removal of the carbon dioxide they respire. This need can only be satisfied if the whole bulk of the soil in which the roots are actively working is permeated with air in contact with the atmosphere and with water. This need is satisfied by the soil having a suitable distribution of pores. If all the pores are large, as in coarse sands, water can drain away rapidly

and air have easy access to all parts of the pore-space, while if all the pores are small, as in silts or clays, water can be held in them against drainage and air cannot enter. The ideal soil must have such a distribution of pore sizes that there are sufficient large pores in contact with each other for adequate gaseous exchange between the soil air and the atmosphere to take place, and sufficient small pores for the soil to be able to hold against drainage a reasonable amount of water that can be utilised by the plant roots.

The pore-space distribution of a soil is dependent on the packing of the soil particles, and if soils were only composed of silt and sand particles, that is non-colloidal particles, the natural packing would be the closest packing, that is the one with the minimum amount of large pores. If all the particles were small all the pores would be small enough to hold water against drainage, so that such a soil could be well drained and yet hold no air, with the consequence that plants growing in it would suffer badly in wet weather. When the soil contains colloidal material, however, it may possess a stable crumb structure, and this increases the average size of the soil pores, mainly by increasing the volume of the larger pores.

The soil aggregates or crumbs, the words are often used synonymously, which form its crumb structure, are the natural fragments into which a soil breaks up, and are collections of soil particles which behave in many respects as new independent soil particles. They may have any size from a large clod to fine dust, and, since they are porous, possess their own internal structure. The soil structure is compounded of the structure of the individual aggregates and of their packing in the soil itself. The pore-space of a crumbly soil is, therefore, different from that of a compact soil, for whereas the pore-space distribution in each aggregate may be the same as in the compact soil, there are a new set of larger pores between the aggregates. In so far as the pore-space in the crumb is the same as in the compact soil the main effect of the crumb structure is to increase the aeration and facilitate the drainage away of the surplus water rather than to increase the amount of water the soil can hold against drainage. Very little is known at the present about how far the pore-space inside a crumb differs from that in the compact soil. If the crumb is itself a cluster of granules, as in some soils, it will evidently be larger, but for the usual soils in this country the difference is not known. It would be a very important property of crumb formation, in those soils which hold an appreciable proportion of their total water in pores so fine that plant roots cannot empty them, if the average diameter of the pores in the crumbs is larger than in the compact soil, for

an increase in average pore diameter causes an increase in the volume of water in the soil which is available to plants.

In the rest of this paper, the discussion will mainly be confined to the crumb structure of the surface soil, for there are not yet sufficient experimental data available for a wider discussion. The structure of the subsoil is of great importance for the growth of agricultural crops since their roots go down several feet. But this structure cannot usually be improved by agricultural operations unless there is some obvious impediment in it, such as a hard pan or a high ground-water table, for, except under these conditions, cultivations much deeper than 6-8 in. do not usually increase the plant growth. Many gardeners and horticulturists do, however, try to improve the subsoil structure by trenching the soil down to 2-3 ft., and this is probably of great advantage for shallow rooting or very quick-growing plants. But in general agriculture it is not economical to try to alter the subsoil structure, and for this reason it has not been studied very much.

A number of experimental methods have been devised to measure the structure of soils. The ideal fundamental measurements are probably to determine the distribution of the volume of water the soil pores can hold as the maximum size of the pore apertures enclosing the water is varied, the stability of this distribution and the rate of gaseous exchange between the soil air and the atmosphere as the moisture content is varied. Unfortunately these measurements have not yet been made, because there are not yet any suitable methods for measuring the volume of water held back by pores of a definite maximum diameter in the range of moisture contents of importance for plant growth when the soil has its field structure.

Three sets of methods to determine the structure of a soil are in use. The first is to measure the volume of air in unit volume of soil at one or at two definite moisture contents, as for example when the soil is holding its maximum amount of water against drainage and when it is air-dry. This method does not easily give sufficiently accurate results for stony soils.

The second set of methods is to determine the rate of flow of water through the soil, and in particular to measure the decrease of velocity of flow with time. This decrease occurs for two reasons. If the soil was initially dry, it swells as it becomes thoroughly wet, so that the pores through which the water is percolating become narrower. Further, some of the soil crumbs break up when wetted into finer particles and crumbs which will fall into and block some of the larger pores. This method can be used for all soils, but the results may be very difficult to interpret.

The third set of methods is to determine the size distribution of the soil aggregates either as they exist in the field or as they exist after having been wetted in water by some particular method. Methods of this type, collectively called methods of aggregate analysis, and particularly those determining the size distribution of water-stable aggregates, have been widely used, for the results can be interpreted fairly easily in terms of field behaviour, but they are not necessarily of direct importance for the air and water regime in the soil.

Doyarenko [1] and some of his co-workers of Russia have tried to determine the most suitable distribution of pore-space and crumb-size for the optimum growth of agricultural crops. From the results of their experiments they stated that, for the humid temperate soils, the volume of the air space in a well-drained wet soil should be about equal to the volume of water present and about equal to half the volume of water present for the semi-arid soils. Their results are ambiguous, however, for they could equally accurately have stated that the soil aggregates should all be larger than $\frac{1}{2}$ mm. and smaller than 3 mm. in diameter. It is probable that both these conditions should hold. The first simply states that in the humid regions the air supply and in the arid regions the water supply is the more important, while the second states that aggregates smaller than $\frac{1}{2}$ mm. merely block the air channels without adding appreciably to the water-holding power of the soil and that the air supply tends to become restricted in aggregates larger than 3 mm. in diameter.

The stability of the soil aggregates, particularly those in the surface soil, is another property of great practical importance. A torrential downpour, such as occurs every now and again in this country, can break down all the aggregates in the surface soil, leaving the surface a wet paste almost devoid of structure. This breaking down occurs more easily on light land, which usually has soft aggregates, than on heavy, which usually has harder ones. On some soils, particularly on some alkali and saline soils, this breakdown of structure occurs merely on wetting the aggregates and without the active mechanical pounding of large raindrops. When a soil, whose surface structure has been destroyed in either of these ways, dries, it usually forms a surface cap or pan which is extremely hard and through which most germinating plants cannot force their way. This cap also hinders the gaseous exchange between the soil air and the atmosphere and reduces the rate with which any further rain can be absorbed, so encouraging surface erosion.

There are not yet any really satisfactory methods for describing

and classifying the different types of crumbs or aggregates that occur in soils. Some soils, such as the virgin black prairie and chernozem soils, possess a very distinctive structure that can easily be described and recognised, but for many soils, particularly for most cultivated soils, the crumb characters most worth while classifying have not yet been agreed upon. Crumbs have been classified by four of their characters, namely their shape, their size, their hardness when dry and their consistency when wet. For a complete classification their pore-space distribution and their water-stability should also be added. The classification in common use in Russia is based on the shape and size of the aggregates as primary characters, with hardness and consistency as secondary. This is well suited to non-arable soils such as old forest, old steppe and old pasture soils, and it is for these it has mainly been developed, but it is not suited to arable soils without modification.

The structure of non-arable or virgin soils can be divided into two main classes, those with simple and those with compound structure. A soil has simple structure when there are no definite aggregates visible to the naked eye, that is larger than about a $\frac{1}{2}$ mm. diameter. The soil may be too sandy to possess a structure, it may be a heavy soil which when dry forms large uniform clods showing no definite structure, or it may be a self-mulching soil whose fine particles are aggregated into crumbs smaller than $\frac{1}{2}$ mm. and which do not stick together to form larger crumbs when dry.

A soil has a compound structure when it breaks up naturally when dry into units larger than $\frac{1}{2}$ mm. in size but smaller than some indefinite upper limit, for large clods showing no structure have already been called simple. This complication is of practically no importance for virgin soils, though it is of great importance for arable soils. The natural aggregates or crumbs are first classified according to their shape, which may be roughly cubical, roughly prism- or column-shaped or roughly plate-shaped. They are then subdivided into those whose sides are smooth, either flat or curved and their edges and corners angular and into those whose sides are irregular and whose edges and corners are rounded. Finally they are subdivided according to their size. Thus on the system used by Zakharov [2] aggregates are said to be granular if they are roughly cube-shaped, have well-defined faces and edges and between 3-1 mm. in size, while they would be called cloddy if their faces and edges were indistinct, and laminar if they had a plate-like structure with definite cleavage planes.

The natural structural units into which a virgin soil breaks down are sometimes called crumbs in contradistinction to aggre-

gates, which then refer to any dry lump of soil. These crumbs have a definite individual existence in the soil for an appreciable number of years, and their classification is not difficult. But in arable soils there is no sharp distinction between crumb and aggregate. The aggregates in the surface layer are not known to have any permanent existence, though many of them have been produced by the natural breaking up of larger clods, and it is aggregates of this type that have not yet been satisfactorily classified.

Attempts have been made to surmount this difficulty by trying to classify the small individual units which compose the larger aggregates. If a dry aggregate is slaked slowly and completely in water, it falls into much smaller aggregates, which may be as large as $1\frac{1}{2}$ mm. but for most arable soils are smaller than $\frac{1}{2}$ mm. These fine aggregates, which have been called ultimate structural elements or the microstructural elements of the soil, possess a much greater water stability than the larger aggregates, probably due solely to their smaller size. It is not known how far these smaller aggregates possess a fairly permanent individual existence in the soil. Kubiena [3] has made a promising attempt to classify these microstructural aggregates by classifying the ways by which the individual sand grains are held together in the aggregate and claims to have described eight distinct classes of the aggregates. But much more work is needed on the classification of microstructure before it is known on what basis to found the classification. It is not even known how far microstructure is a property of cultivated soils only or how far it is possessed by the natural crumbs of virgin soils.

THE CONTROL OF SOIL STRUCTURE

The structure of a soil can in practice be altered by four different methods, namely cultivating the soil, allowing the weather to act on it, adding certain types of manure to it and growing certain crops on it. Most of the experimental work that has been done on these problems has been carried out in Russia, during the last ten years, using the methods of aggregate analysis.

The Effect of Cultivation Implements

Vilensky [4] and his co-workers in the Ukraine have recently introduced a new principle, which, if its generality can be established, will be of great help in interpreting some of the main results of cultivation. They were investigating the effect of working soils at different moisture contents on the size, hardness and water-stability of the aggregates produced by subsequent drying. If less

than a certain amount of water had been added, the effect of kneading was mainly to reduce still further the small amount of aggregation initially present. After a certain moisture content had been reached aggregate formation began to appear and this passed through a well-marked maximum at a definite moisture content. At this stage a well-developed aggregate structure was produced, the aggregates being well distributed between $\frac{1}{2}$ mm. and 20 mm. in size. As the moisture content at the time of kneading increased beyond this, there was a marked formation of large hard clods. The soil not only showed maximum aggregation at this moisture content, but the aggregates had their maximum hardness and water stability at this point, and for many soils this was a very sharp maximum.

These experiments have been repeated elsewhere and the following additional facts stated. The moisture content for this optimum aggregate development is about the same as the sticky point ¹ of the soil, but is lower the greater the pressure used when kneading. The total porosity of the dry soil is a minimum when kneaded at this moisture content, which probably means that the porosity of the individual aggregate has its minimum value then. This point, however, was not directly determined, though it is obviously of great practical importance, for if the pore-space of the aggregates was reduced, it would be an undesirable consequence on heavy land whose aggregates in any case tend to be insufficiently porous.

There is one very important application of this principle that has not yet been confirmed outside Russia. If a soil is cultivated at this critical moisture content the dried aggregates will have their maximum water-stability, consequently possessing their maximum resistance to shattering by rain and, in the alkali soils, to paste formation. As pointed out earlier this general water-instability of the surface tilth of alkali soils presents great difficulties in irrigation husbandry, but some Russians think that if these alkali soils are worked at this critical moisture content, the water-stability of the crumbs is enormously increased. Thus this principle should be of great help in preventing surface caps from forming.

This principle helps to clarify the results of the effects of different cultivation implements on the soil structure. The only way the size of aggregates can be increased by cultivation without ruining the soil structure is to work the soil when it is near this moisture content, as for example to plough it with a mouldboard that will compress the furrow slice while turning it over. If the soil is worked much drier than this, the main effect will be to break up the existing

¹ The sticky point of a soil is the lowest moisture at which the soil will stick to a metal surface.

aggregates, while if it is worked wetter there will be a tendency for large clods to be formed.

A second important point about the action of individual implements is their tendency to produce dust. If the soil is only a little drier than the critical moisture content, the action of all implements, ploughs, cultivators, rotary cultivators and harrows, on the soil structure, is much the same. One implement may make rather more small aggregates stick together to form a larger one while another may break rather more aggregates along their lines of natural cleavage into smaller ones. But when the soil becomes much drier than this certain implements, such as some rotary cultivators and harrows, tend to smash the aggregates by mechanical impact, and this often leads to aggregates being broken along planes that are not natural cleavage planes and in this case dust particles are produced, a phenomenon that does not occur when the soil is damper. This pulverising of the soil aggregates is always undesirable and is particularly harmful in arid regions subject to wind blowing.

The effect of cultivation implements on the porosity of soils is not at all well understood. A number of observations have been made but the results cannot yet be interpreted consistently, possibly because of ignorance of Vilensky's principle. Cultivation can certainly alter the porosity of the soil and in general will increase it, but very little is known about how long this increase lasts into the growing season. Von Nitzsch [5], working in Germany, has demonstrated that if this increase does persist appreciable increases in crop yield occur, but he did not show under what conditions this increase of pore-space could persist.

Effect of Climate

The three main climatic factors that affect the soil structure are the effect of frost, the effect of wetting a dry soil and the effect of drying a wet one. The effect of day-to-day variations of the climate are only of importance on fairly bare soil. Soil under forest, steppe or pasture has a structure that may depend on the average climate over a large number of years, but is nearly constant throughout any one year. The earlier experiments on the effect of frost on the soil structure gave somewhat inconclusive results, probably because most experimenters did not pay sufficient attention to the moisture content of the soil at the time of freezing. Recently the results of some experiments carried out by Jung [6] and the use of Vilensky's principle of a critical moisture content for maximum aggregate formation have probably clarified the position. If the

soil is fairly dry, appreciably drier than Vilensky's critical moisture content, the sole effect of frost is probably to break or to weaken the soil aggregates. If the soil is very wet and the freezing at all fast only very small aggregates are produced. If the soil is at about its critical moisture content the frost produces stable strong aggregates usually between 1-10 mm. in size. These aggregates have usually sharp edges and corners and clearly marked faces and appear as a typical crumb structure.

The effect of the rate of freezing of the soil is not of great importance in practice, since there are usually only small variations in the rate of freezing. If the problem is studied in the laboratory the results found are that the faster the rate of freezing, the smaller and the weaker are the aggregates formed. As an extreme if a wet soil is frozen by immersion in liquid air, the mass on thawing falls down to a uniform paste showing no aggregation due to freezing at all.

The effect of rain on the surface soil is to break up the aggregates. This fact is obvious, though not all the processes at work are understood. As already mentioned, rain can break up aggregates just by the mechanical impact of large rapidly falling drops. The air in the dry aggregates also helps to shatter them on wetting, and some aggregates, such as those of some alkali soils, fall down to a paste on simple wetting. But the main effect of rain is to reduce aggregates to the small elements of microstructure. The heavier the rainstorm, the greater the destruction of aggregates. Merely water-logging a soil for a short time, as for example over winter, has very little effect on the structure of most soils.

The effect of drying a soil is threefold. It tends to undo the work of the rain, by building up aggregates, though these may be large clods. Drying also increases the stability of aggregates in that the cements binding the aggregate together seem to become more water resistant the more they have been dried before re-wetting. But drying also decreases the stability of the aggregates, particularly of large clods, to wetting, for the disruptive effect of the entrapped and adsorbed air in a wetted clod is larger the drier the clod was before being wetted. This disruptive effect is also the greater the more rapidly the dried clod is wetted.

The Effect of Manures

There are a number of vague generalisations in the older soil science text-books on the effects of manures on the soil structure, but there is surprisingly little quantitative information available to check the accuracy of these generalisations or to make them more definite.

The effect of artificial mineral fertilisers, such as the mineral phosphate, potash and nitrogenous fertilisers, have in practice very little if any effect on the soil structure. Those containing soda or potash, particularly nitrate of soda, are said to be very harmful to the soil structure. Unquestionably if sufficiently large doses of nitrate of soda are given to a fallow soil its structure can be spoilt, but there are few, if any, records of this spoiling taking place on commercial farms. At Rothamsted there are three sets of plots which have received annually either 275 lb. or 550 lb. per acre of nitrate of soda for over seventy years, and in only one set is there any suspicion of a harmful effect setting in. This set of plots is now said to be stickier than the other plots in the same field, but there is no indication yet that any other structural property has changed.

Lime and dung are commonly held to have a pronounced beneficial effect on the soil structure. Much of the experimental evidence on the effect of lime is still contradictory, and the present position seems to be that the presence of lime in the soil or the degree of calcium saturation of the soil only affect the size and the stability of the soil aggregates in so far as they hasten the decomposition of the organic matter present, and it is some product of this decomposition that increases the stability of the structure. On this view liming a soil deficient in organic matter will either be of no benefit or may even be slightly harmful to the soil tilth.

Dung is a great improver of soil tilth, particularly if added in very large quantities. Every gardener with a light or heavy soil knows how soon the beneficial effect of digging in large quantities of dung at regular intervals can be seen. The soil works easier, has a better aggregate distribution and probably a better pore-space distribution. Unfortunately there are still very few quantitative determinations of these effects. At Rothamsted on the Broadbalk wheat field, which is a fairly heavy soil, the pore-space on a strip of land that has received 14 tons of dung for almost every year since 1843 has about 37 per cent. pore-space while the neighbouring plot which has been unmanured since then has 34 per cent. pore-space. The dunged soil has also a better and a more stable aggregate structure than the unmanured. Tjulín [7] working near Perm and Ilmenev [8], near Moscow in Russia, each found that the efficiency of dung as a structure improver on acid soils was increased if lime was added at the same time. This is another example of the benefit of lime being due to its power of hastening the decomposition of the dung.

Geltzer [9] working in Turkestan, and other workers elsewhere

in Russia, found that other forms of organic matter are as good, and sometimes better, structure improvers than dung. Ploughing in green crops or even cellulose and potassium nitrate improved the soil structure markedly, but this improvement was shorter lasting than that brought about by dung. Geltzer put forward the generalisation that organic fertilisers only improve the soil structure while they are decomposing, and the faster they decompose the greater will be the improvement in the soil structure. Thus manures rich in readily decomposable substances such as celluloses and hemicelluloses would give a better though a shorter-lived improvement in the soil structure than those rich in less readily decomposable substances such as lignins. The beneficial effect of lime on soil structure, in so far as it hastens the decomposition of the organic matter, is a special case of this generalisation.

The explanation of Geltzer's generalisation will be discussed later. There seems little reason to doubt its validity as judged from numerous experiments reported in the Russian literature, but it has not yet been examined outside Russia.

The Effect of the Growing Crop

It is ancient knowledge that the soil structure under an old pasture or under steppe is much better than in old arable land. Heavy land farmers in this country know that if they leave their land in pasture for three or more years and then break it up, it will work comparatively easily for three or four years, when it can then be laid down to pasture again. Several workers in Russia have followed this effect of pasture on the stability of the soil structure. They find that two to three years is necessary for any noticeable improvement in the structure to take place, and this improvement steadily grows more pronounced for many years. It takes place under grass, clover and lucerne, though naturally it is not possible to keep the last two down for long periods. This building up of structure is rapidly destroyed under arable cultivations, the effect of a six-year ley being small after three to four years. These results are in agreement with the experience of heavy land farmers in this country.

The cause of this improvement will not be discussed here, except to note that it is probably another example of Geltzer's generalisation. For it is probable, but not yet perhaps quite proved, that there is a large supply of readily decomposable organic substances undergoing rapid decomposition under an established grass or clover sward. There is also a large reserve of more resistant material, which decomposes more slowly but which lasts longer, enabling the

cultivated soil to keep its structure for several years. But a time comes when only very resistant organic substances are left in the soil. At this stage a steppe soil that has been cultivated for many years will be almost devoid of structure and yet may have a higher organic matter content than arable soils in other regions which have a much better structure.

THEORIES OF CRUMB FORMATION

The older soil chemists set out to explain why lime benefited the soil. They observed that if a calcareous soil was shaken up with water the suspension cleared rapidly while an acid soil might give a turbid suspension. They knew that if a little lime-water was added to this turbid suspension flocs sufficiently large to be visible to the naked eye would form and settle leaving a clear supernatant liquid. They connected the beneficial effect of lime on an acid soil with the flocculating effect of lime-water on the acid suspension and drew an analogy between floc formation and crumb formation or rather between floc formation and good tilth. The generality of this analogy was increased when it was found that soils could be dispersed in a dilute soda solution to give a stable cloudy suspension and that natural soils containing soda could not usually be cultivated because they could not retain a good crumb structure even if they were given one, a task that was extremely difficult. Flocculation thus came to be considered the cause of good tilth in soils.

This theory was never able to explain the apparent contradictory result that organic matter improved the soil tilth but stabilised soil suspensions, making them more difficult to flocculate. Nor did the theory ever clearly distinguish between crumb formation and crumb stability. But a more serious difficulty was that the so-called deflocculated aggregates of acid soils and the flocculated crumbs of neutral soils could not be distinguished by any simple physical test. It was also found that deflocculated suspensions of calcium soils and clays could be prepared and they yielded just as stable crumbs as those formed from flocculated suspensions. Hence at the present time the primary facts which the flocculation theory set out to explain are now all suspect.

When it became obvious that this simple flocculation theory would not explain the phenomena, instead of it being discarded the concept of the word flocculation was arbitrarily altered. It was then considered that deflocculated pastes of acid and neutral soils suffer irreversible flocculation on drying. Now the essence of the concept of flocculation is that a dispersed substance should settle

out in the form of flocs from the dispersion medium. The process of flocculation can be stretched to cover the separation of the clear dispersion liquid from a semi-rigid gel, but this is a distinct extension of the fundamental concept of flocculation. The concept cannot legitimately or profitably be stretched to include the forcible removal of the dispersion medium from a gel by processes such as drying.

The phenomena related to flocculation and deflocculation in dilute suspensions almost certainly occur in thick soil and clay pastes, but the most suitable terms in which to describe them are not yet known. For example, some dilute deflocculated suspensions of clay in water show colour changes on being shaken or stirred, probably due to the clay particles being orientated along the lines of flow. If the water is sucked out of the suspension by a filter candle this phenomenon becomes more marked as the suspension becomes more concentrated, and even when the suspension becomes so concentrated that it is a thick paste the colour change can still be seen by scratching the surface with a sharp point. If the thick paste is scratched to show a number of these lines of colour and is then carefully dried these lines persist in the dried aggregate, but these aggregates may be very stable in water. This property of colour change with movement is lost if sufficient electrolyte is added to the dilute suspension to cause flocs to form, and in fact a much lower concentration of electrolyte than is necessary to produce floc formation will stop it. If some of the electrolyte solution is sucked out of this flocculated sediment, or if some electrolyte is added to a concentrated deflocculated suspension, a jelly will usually be formed which will not show any colour change on scratching, but which will develop cracks and shafts filled with the clear electrolyte solution and persisting for several months. This phenomenon is not shown by the deflocculated paste. By means of experiments such as these, the concepts of flocculation and deflocculation can be taken over into the study of pastes, although there are not necessarily any methods available for saying if any particular soil paste is flocculated or deflocculated.

Flocculation is no longer considered to be the cause of crumb formation, but it does affect the hardness, the size and the water-stability of the crumbs. Crumbs or aggregates formed by drying a soil or clay paste are harder and larger if the paste was deflocculated than if it was flocculated. Thus a deflocculated paste of a sodium soil yields, on drying, larger and harder aggregates than the paste of the corresponding calcium soil, which may or may not be flocculated. Similarly the addition of an electrolyte, such as sodium

chloride or sulphate, to the sodium clay paste results in smaller and softer aggregates.

The dependence of the water-stability of crumbs on the state of flocculation of the paste from which they were derived seems to be that if a soil paste is flocculated the crumbs formed by drying it are water-stable in the sense that they will not fall back to a paste on re-wetting. If crumbs are not water-stable in this sense, that is if they fall back to a paste on wetting with water, they must have been derived from a deflocculated paste, though only some deflocculated pastes yield water-unstable crumbs on drying. In Nature water-instability in this sense occurs mainly on alkali soils containing appreciable quantities of sodium carbonate or exchangeable sodium. Crumbs formed from these soils may, however, be water-stable if they contain sufficient salts or if they are wetted with saline water and not with rain water. These conditions are present in certain very arid irrigation regions, where the soil structure is stable to the salty irrigation water used, but is ruined by a shower of rain.

The cause of this property of water-stability and instability is not known. Soils and clays only form unstable crumbs if they are saturated with heavily hydrated cations. A sodium soil always gives crumbs that fall down to a paste easier than the corresponding potassium soil, and magnesium soils give less stable crumbs than calcium soils. Anything which depresses the dissociation of the exchangeable cations from the clay surface or, to be more exact, anything which reduces the electrokinetic mobility of the clay particle, increases the water-stability of the crumbs.

The reasons why mineral soils can form crumbs are still debatable. There are at least three possible mechanisms at work, namely cementation of the soil particles by clay, by iron hydroxide and by water films in the very fine pores between the smaller soil particles.

Iron hydroxide can certainly cement soil particles together, but it usually cements them into hard non-porous concretions that behave as stones. Lutz [10] in America has claimed, however, that in certain tropical and sub-tropical soils the amount of crumb structure present in the natural soil is proportional to the amount of free iron hydroxide present in them. Not enough facts are yet known for it to be profitable to discuss the mechanism of this cementation.

The theory that the water films between the fine soil particles are an important factor in keeping soil particles together has been propounded, and though these water films must contribute to the force of cohesion between the soil particles, there are still too many

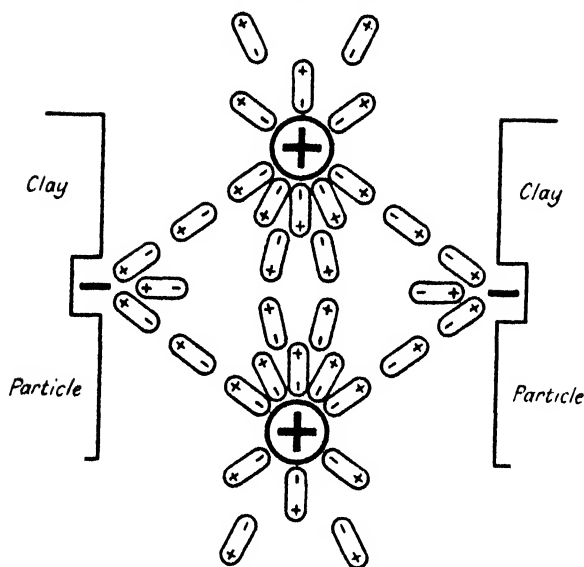
unexplained difficulties to consider this as the sole mechanism involved.

Cementation by clay particles is probably the most important mechanism enabling mineral soils to form crumbs. In soils containing little organic matter or free iron hydroxide it is probable that the clay particles form crumbs and that the silt and sand particles in the crumb are merely enmeshed, acting simply as an inert diluent or filler, and merely weakening and distorting the clay crumbs. This statement may need careful interpretation in those soils in which the silt and sand particles are themselves coated with a layer of clay, but such soils have not been critically examined.

The conditions under which clay particles are bound together in crumbs have been studied in detail by Russell [11], who showed that crumb formation depends not only on the clay but also on its exchangeable ions and on the liquid in its pores. He found that for clays to form hard crumbs their particles must be small, probably less than $\frac{1}{2} \mu$ in diameter, they must have an appreciable base exchange capacity, have fairly small exchangeable cations, such as the simple metallic cations, and be obtained from a paste dispersed in a polar liquid, such as water or ethyl alcohol, whose molecules are small. A polar liquid is one whose molecules have a permanent electric dipole moment due to a concentration of positive charge on one side and of negative on another of the molecule. The truth of this last condition can be easily demonstrated, for crumbs derived from a suitable clay paste dispersed in water or ethyl alcohol will be hard, those derived from the same clay dispersed in nitrobenzene soft, while no crumbs at all will be formed if the same clay was dispersed in a non-polar liquid such as benzene or carbon tetrachloride.

Russell explained these results of crumb formation by assuming that the bonds which hold two clay particles together are dissociated exchangeable cations and orientated molecules of the polar dispersion liquid. The residual negative charges on two neighbouring clay particles and the positive charges on the dissociated cations orientate the polar molecules between them, as shown diagrammatically on p. 675, and it is bridges of these orientated molecules and dissociated cations that bind two clay particles together.

This theory seems to be able to explain most of the phenomena of crumb formation but it suffers from the defect that it cannot yet be used for quantitative prediction of crumb strength. According to this theory the strength of a clay crumb depends on the strength and the number of these bridges or bonds between the individual clay particles. Unfortunately these two factors, bond strength and



bond number, which are fundamental in the theory, cannot be separated in any particular case, as there are no methods of measurement yet available for determining the number of cations that have dissociated from the clay surface. Thus, while the theory can predict the relative strengths of different bonds, it can only explain the observed facts of the relative hardness of crumbs by assuming the relative degree of ionic dissociations. Fortunately the assumptions needed are in accord with commonly accepted ideas on relative ionic dissociations, but our confidence in the theory would be greatly strengthened if it could predict the relative hardness of crumbs when the degree of dissociation of the exchangeable cations in the clay crumbs was determined independently.

The mechanism by which organic matter binds soil particles together into crumbs is still unknown. The organic matter is commonly pictured as acting as a cement which becomes more stable to rewetting the more it has been dried. Very little is known about what fractions of the soil organic matter take part in this action. It is known that the colloidal fraction dispersable in a dilute soda or ammonia solution, the so-called humic acid fraction, can bind fine sand and silt particles together into fairly stable crumbs. Some workers have claimed that only a certain fraction of this dispersable organic fraction plays any active rôle in crumb formation, but their experimental evidence is unconvincing. It seems to be a general property of this dispersable colloid.

Geltzer's generalisation, however, may open up another line of research. This generalisation states, as already mentioned, that the more rapid is the rate of decomposition of the organic matter in the soil, the better will be the soil structure. The obvious explanation of this generalisation is that the substance responsible for this improvement of structure is a product of microbial activity and is itself fairly easily decomposed. It is probable, but not yet proved, that this improvement in structure is accompanied by the production of a mucus, that is of a substance that is sticky when wet. If this is found to be true Geltzer's generalisation reduces to the statement that the greater rate of decomposition of organic matter in the soil, the larger is the amount of mucus in it and, consequently, the better is the soil structure. This has not answered the question of the composition of the mucus or of how it is produced, nor whether it is identical or similar to that of the readily dispersable organic colloids already discussed.

The last decade has seen a great revival of interest in the effect of soil structure on the biotic conditions in the soil, largely due to the introduction of new methods of aggregate analysis. These methods have only recently been used extensively and it is still too early to say how far they will be able to give the type of information needed for interpreting the effect of soil structure on the growth of plants.

REFERENCES

1. For a full account of this work in German, with references to the original Russian papers, see M. KRAUSE, *Landw. Jahrb.*, **73**, 601-90 (1931).
2. ZAKHAROV, S. A. *Russian Pedological Investigations*, No. 2. Acad. Sci., Leningrad (1927).
3. KUBIENA, W. *Soil Research*, **4**, 380-412 (1935), and *Bodenk. Pfl. Ernähr.*, **2**, 1-23 (1936).
4. VILENSKY, D. G. *Trans. 1st Comm. Int. Soc. Soil Sci. (Versailles)*, 97-108 (1934). See also *Pedology* (1933), 443-63 and (1934) 34-60.
5. VON NITZSCH, W. "Bessere Bodenbearbeitung," *Reichs Kurat. f.d. Techn. i.d. Landw.*, Heft 70 (1936).
6. JUNG, E. *Koll. Beih.*, **32**, 320-73 (1931).
7. TJULIN, A. T., and BIRJUKOVA, E. V. *Chem. Soc. Agric.*, No. 2, 113-22 (1933).
8. ILMENEV, S. I. *Chem. Soc. Agric.*, Nos. 11-12, 153-60 (1935).
9. GELTZER, F. Y. *Trans. 1st Comm. Int. Soc. Soil Sci., Soviet Sect.*, A.2, 73-8 (1934).
10. LUTZ, F. J. *Proc. Soil Sci. Soc. America*, **1**, 43-5 (1937).
11. RUSSELL, E. W. *Phil. Trans.*, A, **233**, 361-89 (1934).

MAGNETIC ANISOTROPY OF CRYSTALS

By KATHLEEN LONSDALE, D.Sc.

Davy Faraday Laboratory, Royal Institution, London

HISTORICAL INTRODUCTION

THE attraction of the mineral magnetite for iron and the power it could impart to pieces of iron of similarly attracting other pieces, were among the earliest observed scientific phenomena, speculations as to the origin of these "magnetic forces" having been recorded by Lucretius well over 2000 years ago.

Similar magnetic properties were observed in cobalt and nickel soon after the discovery of those elements [1]. Isolated observations in the late eighteenth and early nineteenth century showed that a magnet exerted a repulsive force on bismuth and one or two other substances [2]. These observations were not followed up and excited little interest at the time.

In 1824 the mathematician Poisson published a remarkable memoir on the theory of magnetism which, although based on the untenable hypothesis of movable "magnetic fluids," gave a satisfactory mathematical formulation of the quantitative facts of magnetic action as then known. He suggested [3] at the same time that in crystalline matter the small "magnetic elements," of which he assumed magnetizable matter to be constituted, might be non-spherical and symmetrically arranged, and remarked that a finite spherical portion of such a substance would, when in the neighbourhood of a magnet, act differently according to the different positions into which it might be turned with its centre held fixed. "Such a circumstance not having yet been observed," he excluded the consideration of crystalline structure from his researches and applied his theory only to matter consisting either of spherical magnetic elements, or of non-symmetrically disposed elements of any form.

This *magnetic anisotropy* or variation of intensity of magnetization with direction in crystalline matter, so clearly visualized by Poisson, was observed some seven years after his death in 1840. In 1845, Faraday, using a powerful electromagnet, found that quite

apart from the iron group of elements, a large number of substances were affected by a magnetic field and that the magnetic action could be either attractive or repulsive, the latter effect being particularly strong in the case of bismuth. On suspension in his magnetic field, which was not very uniform, an elongated mass of a "magnetic" substance would tend to set itself with its longest dimension in the line joining the N. and S. poles of the electromagnet (*i.e. axially*), whereas repulsive forces would cause a similarly elongated mass of a "diamagnetic" substance to set its longest dimension at right angles to the line joining the poles (*i.e. equatorially*). These experiments, and the sound explanations which Faraday gave of them, led many other workers to explore the same field, both from an experimental and from a theoretical point of view.

The German scientist Plücker had a magnet built of the same size and power as that described by Faraday, his primary object being to investigate whether the fibrous constitution of plants affected their magnetic behaviour; in the course of his work he decided to try whether crystalline structure had any influence. His first experiment gave a positive result. A plate of tourmaline, $12 \times 9 \times 3$ mm., when suspended in the magnetic field with its optic axis vertical, set itself axially, as an ordinary "magnetic" substance would do. When, however, the crystal was hung with its optic axis horizontal, the plate set itself equatorially, like a diamagnetic. Further experiments were carried out on magnetic and diamagnetic crystals of various symmetries, and Plücker deduced the existence of an independent force, in no way connected with the magnetism or diamagnetism of the mass of the crystal [4]. He came to England in 1848 and showed his results to Faraday, who himself took up the research. Faraday's intense interest in the subject is evidenced by the fact that over 200 pages of his diary, roughly one-sixteenth of the whole, are occupied by descriptions of experiments on various "magnecrystalline" substances and interpretations of these [5]. He defined a *magnecrystalline substance* (or as we should now say "a crystalline substance showing magnetic anisotropy") as "one which in the crystalline state could conduct on wards or permit the exertion of the magnetic force with more facility in one direction than another." This anisotropy was at first deduced from the preferential orientation of crystals suspended in a magnetic field, but in 1850 Faraday succeeded in proving that bismuth was actually repelled with different degrees of force in different directions. William Thomson, in the course of a paper on the theory of magnetic induction in crystalline and non-crystalline substances [6], remarked that no crystal had yet been found

which was magnetic in one direction and diamagnetic in another. Such an effect has, in fact, been discovered, but only within the last few years, for some very specialized alloys of bismuth [7] and of antimony [8].

Plücker had tried to explain the behaviour of crystals in a magnetic field in terms of the position of their optic axes; Tyndall and Knoblauch found exceptions to Plücker's laws, and believed that an explanation was possible in terms of cleavage directions, but this theory also was found wanting [9]. Faraday himself hoped to find some relation between magnetism and the forces which build up crystal structure, and brought to this investigation an energy and thoroughness which caused Tyndall to write in 1868 [10]: "I have worked long myself at magnecrystalline action, amid all the light of Faraday's and Plücker's researches. The papers now before me were objects of daily and nightly study with me eighteen or nineteen years ago; but even now . . . they astonish me. Every circumstance connected with the subject; every shade of deportment; every variation in the energy of the action; almost every application which could possibly be made of magnetism to bring out in detail the character of this new force, is minutely described. The field is swept clean, and hardly anything experimental is left for the gleaner."

Although Tyndall might be surprised at the amount gleaned from this field within the present century and particularly within the last few years, it is a fact that little new knowledge concerning the magnetic anisotropy of crystals was forthcoming for some thirty years after the time of Faraday's experiments, when a few quantitative measurements were made on crystals of bismuth, calcite and quartz [11].

GENERAL BEHAVIOUR OF CRYSTALS IN A MAGNETIC FIELD

A discussion of the modern work in this subject may well be preceded by a description of the general factors affecting the behaviour of a crystalline substance when placed in a magnetic field.

Diamagnetism.—Diamagnetism is a fundamental property of all matter. That is to say, an imposed magnetic field will always cause an extra circulatory motion, or *precession*, of the electron orbits about the field axis, the atoms thus acquiring a magnetic moment which is opposed to the inducing field and is directly proportional to the field strength. The factor of proportionality, the *diamagnetic susceptibility*, is dependent on the electronic structure of the atoms and on nothing else. It is independent both of temperature and of field strength except in so far as these may influence the electron

density distribution. The susceptibility (magnetic moment/field strength) per unit volume is usually denoted by κ , the susceptibility per unit mass by χ_s , and the gram-atomic susceptibility (χ_s . atomic weight) by χ_A . Classical theory and quantum mechanics give the same expression for χ_A for the case of an atom having spherical symmetry, or for an aggregate of atoms having statistical spherical symmetry, namely

$$\chi_A = - \frac{Ne^2}{6mc^2} \cdot 10^{10} \frac{\Sigma \bar{r^2}}{n} = - 2.83 \cdot 10^{10} \frac{\Sigma \bar{r^2}}{n}$$

where $\bar{r^2}$ is the average mean square radius of the n electron orbits in a single atom, or more generally a measure of the average electron density distribution. The susceptibility is normally of the order of 10^{-6} c.g.s.e.m.u., hence the diamagnetic effect is very small and a strong field (several thousand gauss) is usually required to induce any appreciable intensity of magnetization. If capable of translation a diamagnetic substance will move from the stronger to the weaker part of a magnetic field. A rod of isotropic diamagnetic material suspended in a uniform field will not move, either laterally or rotationally. There must theoretically be a very feeble tendency for it to set itself axially [9], but this effect is too small to be observed. In a non-uniform field a rod of isotropic diamagnetic material will set itself across the lines of force if free to rotate, because in that equatorial position the demagnetizing force is a maximum. If the material is not isotropic the above effects still exist and the rotational effect due to shape may mask the magnecrystalline effect unless the magnetic field used is as uniform as possible, or unless the material is used in the form of a sphere.

Paramagnetism.—It very often happens that the individual ions, atoms or molecules which constitute a particular substance are themselves little elementary magnets, that is to say, they possess a resultant magnetic moment. Ordinarily, these elementary vectors are arranged at random, so that the substance as a whole is non-magnetic. When an external magnetic field is imposed, there is a tendency to alignment of the atomic moments, that tendency being restricted by a number of factors, including the kinetic energy of the atoms themselves (dependent upon temperature), interaction with neighbouring atoms (dependent on the nature of the substance) and crystalline symmetry. The very existence of a regular arrangement of atoms in crystals implies the presence of a strong field of force, sometimes called a *crystalline field*, whose effect is to limit the response of the elementary magnets to the external magnetic field. The induced paramagnetic effect is in the same

sense as the external field and it is generally much greater than the universal diamagnetic effect. The latter may consequently be completely masked and is only observable in cases where the elementary particles possess no resultant magnetic moment of their own and where this kind of paramagnetism therefore does not exist.

The *paramagnetic susceptibility* (similarly defined as the induced magnetic moment/field strength) is independent of field strength except for very low temperatures and very strong fields (theoretically, of course it must be possible to reach a state of saturation, when all the elementary atomic vectors point in the same direction), but its dependence on temperature is given by the expression

$$\chi_A = \text{const.}/T - \theta,$$

where T is the absolute temperature and θ is known as the *Curie temperature*. This equation only holds for values of T greater than and not too close to θ . Below θ , whose value is characteristic of the substance considered, most substances so far examined become ferromagnetic.

Ferromagnetism.—The characteristic properties of ferromagnetism are *hysteresis* and *remanence*; the intensity of magnetization is no longer directly proportional to the field strength and the dependence on temperature may be quite different from that for a paramagnetic substance. Saturation is produced by comparatively low fields and alignment of the elementary magnets persists when the external field is removed. These elementary magnets in the case of ferromagnetic materials are not the individual atoms, but large groups or *domains* of adjacent atoms. Within these domains, whose average magnetic moment is from 10^{10} to 10^{15} times as great as that of a single atom, and whose maximum volume is about 10^{-8} cm.³, there is a spontaneous magnetization due to a tendency to parallel alignment of the electron spins. Complete saturation within the domains can only occur at absolute zero, but at any given temperature each domain possesses a certain magnetic moment appropriate to its size, although the directions of magnetization of the domains may be distributed at random. The steep parts of the hysteresis curve correspond to sudden changes of direction of magnetization throughout domains due to the imposition of the external field. Saturation at any given temperature corresponds to a complete alignment of these directions of magnetization, though not, of course, of the electron spins within the domains, except at absolute zero.

Although the intensity of magnetization in ferromagnetics is far greater than that in paramagnetics, they behave similarly in

respect of their movements in a magnetic field. Both tend to move towards the strongest part of a field. In either a uniform or a non-uniform field an isotropic rod, if free to rotate, will set itself axially, *i.e.* along the lines of force, the tendency to rotation being greater, the greater the non-uniformity of the field. Even in a uniform field, however, this tendency is no longer negligible in the case of ferromagnetic or strongly paramagnetic materials. Where it threatens to mask an expected magnecrystalline effect it may, however, be annulled by surrounding the rod with a medium of its own mean susceptibility [12]. The use of a sphere of the material would eliminate the "shape" effect, but care must be taken that in grinding the sphere or spheroid strains are not set up which would introduce an extraneous magnetic anisotropy.

INFLUENCE OF CRYSTAL SYMMETRY

A truly isotropic material is one in which the atoms are all arranged at random, as for instance in a gas, most liquids and amorphous solids. A substance may be effectively isotropic if it is composed of microcrystals of absolutely random orientation. Diamagnetic and paramagnetic substances which crystallize in the cubic system also in general show no difference in behaviour, whatever their orientation in a magnetic field. In crystals of low symmetry, however, there are only three, mutually perpendicular directions, known as the *axes of principal magnetization*, along which the direction of magnetization coincides with the direction of the applied field. The susceptibilities along these directions are called the *principal susceptibilities*, and their values are in general unequal. A piece of non-cubic crystalline matter suspended in any magnetic field will tend to orientate itself so that the axis of maximum susceptibility in the plane of rotation lies along the lines of force. If the substance is diamagnetic (χ negative) this will be the axis of minimum numerical susceptibility. The magnetic anisotropy $\Delta\chi$ is sometimes expressed as the difference of two principal susceptibilities, sometimes as their ratio. Uniaxial crystals have only two principal susceptibilities, along and perpendicular to the principal crystal axis. Such crystals are of special interest, because they include many metals and some of the commoner minerals. The average susceptibility as determined from a crystal powder is found to be the same as the mean of the three principal susceptibilities, when these are measured separately: $\bar{\chi} = \frac{1}{3}(\chi_1 + \chi_2 + \chi_3)$.

Ferromagnetic crystals are unique in that the ease of magnetization in various directions, even in cubic crystals, is not the same.

There is no distinction between the crystallographically equivalent directions, such as [100] $\bar{[100]}$ [010], etc., but the ease of magnetization along such directions as [100] and [111] may differ considerably. It is clear that ferromagnetic anisotropy cannot be defined in terms of values of the susceptibilities along mutually perpendicular axes; it is expressed instead in terms of the work required to magnetize unit volume of the crystal to saturation in any given direction.

$W_\alpha = K_0 + K_1(\alpha_2^2\alpha_3^2 + \alpha_3^2\alpha_1^2 + \alpha_1^2\alpha_2^2) + K_2\alpha_1^2\alpha_2^2\alpha_3^2$ gives the value of this work/unit volume, to a first approximation, for a direction of magnetization making angles whose cosines are $\alpha_1, \alpha_2, \alpha_3$, with the cubic crystal axes. K_0 is the energy of magnetization along a cubic axis; K_1 and K_2 are known as the first and second *anisotropy constants*, only the variations in K_1 having been studied with any great degree of precision.

DETERMINATION OF ANISOTROPY

Determination of the anisotropy of diamagnetic and paramagnetic crystals involves the location of the principal susceptibility axes and measurement of the susceptibilities along those axes. In orthogonal crystals the axes of principal susceptibility coincide with the crystal axes, and in the monoclinic system one principal axis, χ_3 , coincides with the symmetry axis of the crystal. A procedure for the accurate location of the other two axes in the monoclinic system, or of all three axes in the triclinic system, has been described recently by Krishnan and his collaborators [13], whose method gives results correct to within a degree or so. They use crystals of natural shape, and therefore, in order to eliminate the effect of the shape and leave only the effect due to crystal anisotropy, they use a magnetic field as uniform as possible, if necessary surrounding the crystal by a liquid of its own mean susceptibility.

Instead of measuring absolute susceptibilities along the three principal directions, it is generally much more accurate to measure the susceptibility along one axis only, preferably along the axis of maximum susceptibility, and then, by a differential method, to determine the difference of susceptibility between that and other directions. Various methods of determining the absolute susceptibility in a given direction have been used [14], but the one most useful for small single crystal specimens is that devised by Rabi [15] and modified by later workers in the same field [16]. It depends on the fact that when the volume susceptibility of the medium surrounding a crystal is equal to the volume susceptibility of the

crystal in any particular direction, then there will be no lateral force acting on the crystal even in a non-uniform field. The crystal may be suspended by a fine quartz fibre in such a way that the axis of maximum susceptibility can set itself naturally along the lines of force, or it may be freed from all external constraint by using as the surrounding medium a mixture of two liquids each of the same density as that of the crystal but of different susceptibilities. The susceptibility of the mixture is varied until there is no lateral movement of the crystal, and it is then measured by the Gouy or any other suitable method.

If a crystal is suspended by a vertical quartz fibre in a uniform magnetic field, the force tending to bring its axis of maximum susceptibility in line with the field will be directly proportional to the difference of principal susceptibilities in a horizontal plane. That force can be computed, and the anisotropy deduced, either by a method involving the time of oscillation in the magnetic field, or by measuring the torque on the quartz fibre which will exactly balance the restoring force due to the field [13]. The last method has been so refined by Krishnan and his co-workers that they have been able to measure the anisotropies of crystals weighing only 0.1 mg. [16]. The volume susceptibilities of most diamagnetics are of the order of 10^{-6} c.g.s.e.m.u. or less; those of the most powerful paramagnetics may perhaps be one hundred times as great. In either case the *permeability* (total flux per unit volume/field strength; $\mu = 1 + 4\pi\kappa$) is approximately unity. The permeabilities of ferromagnetics, especially in the direction of easy magnetization, can attain values up to a million, and a different technique is therefore required for their measurement. Torsion methods involve the use of a disc or oblate spheroid, cut from a single crystal and suspended in the magnetic field in various orientations. Measurements of the torque exerted by the applied field will give the first anisotropy constant K , directly [17], or magnetization curves may be plotted for those directions in which the magnetization and effective magnetizing field remain parallel, that is, for the [100], [110] and [111] directions in a cubic single crystal. Williams has recently developed a very elegant method by means of which the anisotropy may be measured not only for high fields, in which the magnetization approaches saturation, but also for low fields, where normally a large demagnetizing field in the specimen itself introduces uncertainties. From a large single crystal some $1 \times 1 \times 2$ cm. he cuts hollow parallelogram sections ("picture-frames") the sides of which are parallel to certain crystallographic directions. These are carefully etched and annealed to remove all strain due to the cutting

processes. The crystals then form closed magnetic circuits, which are wound with a primary and secondary, the magnetization curves being plotted with the help of a Haworth fluxmeter [18].

MODERN LINES OF INVESTIGATION

Diamagnetic Crystals.—Since diamagnetism depends only on the electron structure of matter, it may be expected to throw light on that particular problem. The *mean* susceptibility of organic compounds is, as Pascal pointed out some thirty years ago [19], an additive property, in that the molecular susceptibility χ_M of a compound having the formula $\Lambda_\alpha B_\beta C_\gamma \dots$ is given by the equation $\chi_M = \Sigma \alpha \chi_A + \lambda$, where $\alpha, \beta \dots$ are the numbers of atoms of susceptibilities $\chi_A, \chi_B \dots$ and λ is a small constitutive correction factor, determined by the valency bonds. Even in the solid state it is clear therefore that the mutual influences of neighbouring molecules must be negligible. The anisotropy of a single crystal must be due to the anisotropy of the unit cell, which in its turn is the resultant anisotropy of the component individual molecules. If the electron distribution in the molecule is such that the molecule is approximately isotropic from a magnetic point of view, then the crystal will show little or no anisotropy. If, however, the molecule possesses considerable anisotropy, the degree to which the crystal reveals that anisotropy will depend entirely upon the arrangement of the molecules. The molecules may be arranged in more or less parallel positions (layer or chain structures), in which case the crystal anisotropy will be nearly as large as that of the molecule; it cannot be larger. Or the molecules may be so arranged that their anisotropies cancel out, as for example in cubic crystals. Most recent research has been concerned with layer structures.

Inorganic and Organic Salts.—Carbonates, nitrates and oxalates have been found to possess a relatively high anisotropy as compared with the corresponding sulphates and selenates. The minimum (maximum negative) susceptibility is normal to the plane of the carbonate, nitrate or oxalate radicle as revealed by X-ray analysis. The sulphate and selenate groups, being possessed of approximately tetrahedral symmetry, are relatively isotropic in their opposition to the applied magnetic field [12] [16].

Ring Compounds.—The most striking diamagnetic anisotropies are shown by the aromatic organic compounds, whose molecules contain single or condensed benzene [13], cyanuric or phthalocyanine rings. Since many of these compounds have undergone a complete structure determination by X-ray methods, and the orientations of their molecules in the crystal framework are accurately known,

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it has been possible to deduce, from the principal crystal susceptibilities and the molecular direction cosines, the principal susceptibilities of the individual molecules. Some results are given in Table I.

TABLE I.

Substance and Formula.	Gram. Molecular Susceptibilities of Molecule.		
	$-K_1 \cdot 10^6$	$-K_2 \cdot 10^6$	$-K_3 \cdot 10^6$
Naphthalene, $C_{10}H_{14}$	56.1	53.9	169.0
Anthracene, $C_{14}H_{18}$	75.8	62.6	251.8
Chrysene, $C_{18}H_{22}$	88.0	83.3	310.8
Cyanuric trichloride, $C_3N_3Cl_3$	70.9	71.2	101.3
Metal-free phthalocyanine, $C_{22}N_8H_{18}$	165	120	982

X-ray analysis has shown that all these molecules possess a planar configuration; K_1 , K_2 lie in the plane of the molecule, K_3 is perpendicular to that plane [20].

Various suggestions have been put forward to explain the large diamagnetism along K_3 in terms of large electron orbits in the molecular plane [21], the most fruitful suggestion being that it is the aromatic or resonance electrons (one to each carbon or nitrogen atom in the ring) which occupy orbits of molecular instead of atomic size. Even more recently London [22] has provided a satisfactory quantum mechanical basis for the molecular orbital theory in the case of aromatic molecules within a magnetic field, and has obtained excellent numerical agreement between theory and observation.

In favourable cases, where the molecular anisotropy can be estimated with some accuracy, it is sometimes possible to deduce the molecular orientation in crystals from magnetic measurements alone, thus providing valuable assistance in the initial stages of an X-ray investigation [23].

Graphite.—Carbon crystallizes in two forms, diamond (cubic and therefore isotropic), and graphite (hexagonal). Graphite is strongly anisotropic, its gram-atomic susceptibilities along and normal to the hexagonal axis being $\chi_{\parallel} = -264 \cdot 10^{-6}$, $\chi_{\perp} = -6 \cdot 10^{-6}$ [24]. The usual explanation for the large value of χ_{\parallel} , which is strongly dependent on temperature, particle size and presence of impurities, is that there are loosely bound electrons occupying large orbits in the basal plane.

Bismuth and Other Diamagnetic Semi-Metals and Alloys.—The mean mass susceptibility of bismuth in the solid state is about $-1.35 \cdot 10^{-6}$ at room temperatures. Just below the melting-point

it is $-1.02.10^{-6}$; that of molten Bi is only $-0.08.10^{-6}$. Similar but less striking changes take place for other metals and semi-metals [25], whereas the mean susceptibilities of inorganic and organic salts vary little, if at all, with change of state [26, 16]. This clearly indicates a quantitative dependence of susceptibility upon the electronic structure of the metals, and Jones [27] has succeeded in explaining the general features of the anisotropy of bismuth [28] and of bismuth alloys [29] in terms of the Bloch theory of metals.

Paramagnetic Crystals.—Table II shows the mean susceptibility and magnetic anisotropy of some of a group of isomorphous (i.e. structurally similar) crystals examined by Krishnan and his collaborators [30, 12].

TABLE II

Substance.	Mean Gram-mol. Susceptibility $\bar{\chi} \cdot 10^6$	Gram-mol. Anisotropy at Room Temperature $\Delta\chi \cdot 10^6$
$\text{FeSO}_4(\text{NH}_4)_2\text{SO}_4 \cdot 6\text{H}_2\text{O}$	11480	$\begin{cases} \chi_1 - \chi_2 = 2582 \\ \chi_1 - \chi_3 = 213 \end{cases}$
$\text{CoSO}_4(\text{NH}_4)_2\text{SO}_4 \cdot 6\text{H}_2\text{O}$	9590	$\begin{cases} \chi_1 - \chi_2 = 3023 \\ \chi_1 - \chi_3 = 1541 \end{cases}$
$\text{NiSO}_4(\text{NH}_4)_2\text{SO}_4 \cdot 6\text{H}_2\text{O}$	3067	$\begin{cases} \chi_1 - \chi_2 = 110 \\ \chi_1 - \chi_3 = 106 \end{cases}$
$\text{MnSO}_4(\text{NH}_4)_2\text{SO}_4 \cdot 6\text{H}_2\text{O}$	13830	$\begin{cases} \chi_1 - \chi_2 = 8.7 \\ \chi_1 - \chi_3 = 6.0 \end{cases}$
$\text{ZnSO}_4(\text{NH}_4)_2\text{SO}_4 \cdot 6\text{H}_2\text{O}$	Diamagnetic	$\begin{cases} \chi_1 - \chi_2 = 1.2 \\ \chi_1 - \chi_3 = 0.8 \end{cases}$
$\text{NiSO}_4 \cdot \text{K}_2\text{SO}_4 \cdot 6\text{H}_2\text{O}$	3970	$\begin{cases} \chi_1 - \chi_2 = 158 \\ \chi_1 - \chi_3 = 155 \end{cases}$
$\text{MnSeO}_4 \cdot \text{Ti}_2\text{SeO}_4 \cdot 6\text{H}_2\text{O}$	14290	$\begin{cases} \chi_1 - \chi_2 = 10.2 \\ \chi_1 - \chi_3 = 8.5 \end{cases}$

The magnitude of both $\bar{\chi}$ and $\Delta\chi$ are clearly dependent on the nature of the paramagnetic ion, that is, on the ion containing an incomplete electron group or an unpaired spin. If there is no such ion, the salt is diamagnetic and the small anisotropy is due to differences in the projected electron density distribution in the directions of the principal axes.

The quantum theory of paramagnetism has successfully explained many of the experimental results [31]. It relates the behaviour of the elementary magnets to the spectroscopic state of the ions, and cannot be fully understood except by the use of spectroscopic terms. These elementary magnets, which are the electrons themselves, possess angular momentum (and therefore a magnetic moment) in virtue of their *orbital motion* about the nucleus or some other centre and also because of their *spin motion*, each electron

being an elementary gyroscope. Most of the electrons compensate each other but paramagnetism arises where there is a resultant moment. In the presence of a magnetic field these moments, normally distributed at random, assume certain discrete orientations, whose number is limited by the spectroscopic state of the ion; the energy required to bring about alignment of these moments with the direction of the field varies from one orientation to another.

The presence of an electric field, such as occurs in crystals, limits the initial orientations of the orbital moment in the field, without affecting the spin moment except indirectly. If the crystalline field is asymmetric, it follows that a magnetic carrier whose orbital moment has been thus "frozen" will be less free to align itself in some directions than in others. The crystal will be magnetically anisotropic. Magnetic carriers which have no resultant orbital moment, but only a spin moment, though they may possess considerable paramagnetism, will show little or no anisotropy, because of the comparative freedom of the spin moment from crystalline influence.

Rare-earth Salts.—The mean susceptibility of rare-earth salts has been measured with considerable precision; it indicates that in their ions there is a strong coupling between the orbital and spin moments, probably due to the fact that the incomplete group of electrons is a sub-shell which is shielded by an outer inert gas configuration of eight electrons of higher quantum number. It was formerly believed that in these salts the crystal field was predominantly cubic, owing to the probable octahedral arrangement of six oxygen atoms about the paramagnetic ion. Recent measurements by Krishnan and Mookherji [32] have shown that the magnetic anisotropy is considerable, indicating that there must be a rhombic crystal field of definite orientation acting on the ions, the departure from cubic symmetry being quite large.

Salts of the First Transition Series of Elements.—In ions of the transitional groups the incomplete sub-shell lies outermost and the orbital moments, being relatively loosely coupled to the electron spin, will be easily affected by a disturbing crystalline field; marked crystal anisotropy and considerable deviations from the Curie law¹ at low temperatures are therefore to be expected. The anisotropy of the mineral *siderose* (mainly FeCO_3) is so large that it has been used, in a direct reading instrument called a gaussmeter, for the measurement of magnetic field strengths [33]. Where the orbital moment is zero, as for example in the Gd^{+++} , Fe^{+++} and Mn^{++} ions, experiment agrees with theory in showing little crystal aniso-

¹ $\chi = \text{const.}/T$, where T is the absolute temperature.

tropy, and a close adherence to the Curie law [34]. From a study of the small anisotropy that does still exist Krishnan and Banerjee were able to deduce the Curie temperatures of certain manganous salts and hence to predict the entropy-temperature and specific heat temperature curves of their crystals in the neighbourhood of 0.1° K. [12].

It will be seen from Table II that the anisotropy of Ni^{++} salts is much less than that of Co^{++} salts. The quantum theory has been strikingly successful in explaining this apparent anomaly and has predicted that, whereas in the above salts the ions are octahedrally surrounded by negative charges, if a tetrahedral field could be attained the order of anisotropy would be reversed [35]. Krishnan and Mookherji have recently measured the anisotropy of single crystals of $\text{Cs}_2[\text{CoCl}_4]$ and of $\text{Cs}_2[\text{CoCl}_4]\text{Cl}$, in which there is such a tetrahedral field, and have found, in agreement with the prediction, that here the anisotropy of Co^{++} is very small [36].

Complex Salts.—Little work has yet been done on the anisotropies of complex salts. An interesting investigation by Jackson on $\text{K}_3[\text{Fe}(\text{CN})_6]$ has revealed an anisotropy of nearly 100 per cent. at low temperatures [24]. Quantum mechanical methods have been applied by Howard [37] to give a quantitative explanation of this effect.

Ferromagnetic Crystals.—The domains in ferromagnetic crystals are not apparently identical with the crystalline grains which form the mosaic structure of a single crystal. The electrostatic exchange forces which bring about the initial alignment of electron spins are very much stronger than the crystalline forces, although the latter determine the particular direction along which alignment shall take place. The direction of easy magnetization in single crystals of iron is along the cubic axis. In an unmagnetized iron crystal, therefore, the elementary magnets (spin directions in individual domains) are pointing in six mutually perpendicular directions. Initial magnetization at very low fields corresponding to the portion AB of the magnetization curve (see Fig. 1), takes place by very small displacements of the boundaries of the domains [38]. Domains already magnetized more nearly in the direction of the applied field gain a few atoms at the expense of less favourably magnetized domains. For somewhat higher fields magnetization proceeds by the discontinuous orientation of the spins of individual domains [39], so that they are brought, one at a time, into the direction of easy magnetization nearest to the field direction. This corresponds to the steep part BCD of the magnetization curve; and if the imposed field corresponds to a cubic axis, saturation is reached when

all the elementary magnets are aligned parallel to that axis. If, however, the field is imposed in some other direction, say $[110]$, further work must be done in rotating the groups out of the direction of easy magnetization and into the field direction (portion DE of magnetization curve). All this is shown very diagrammatically in Fig. 1, only two of the possible six initial orientations being illustrated.

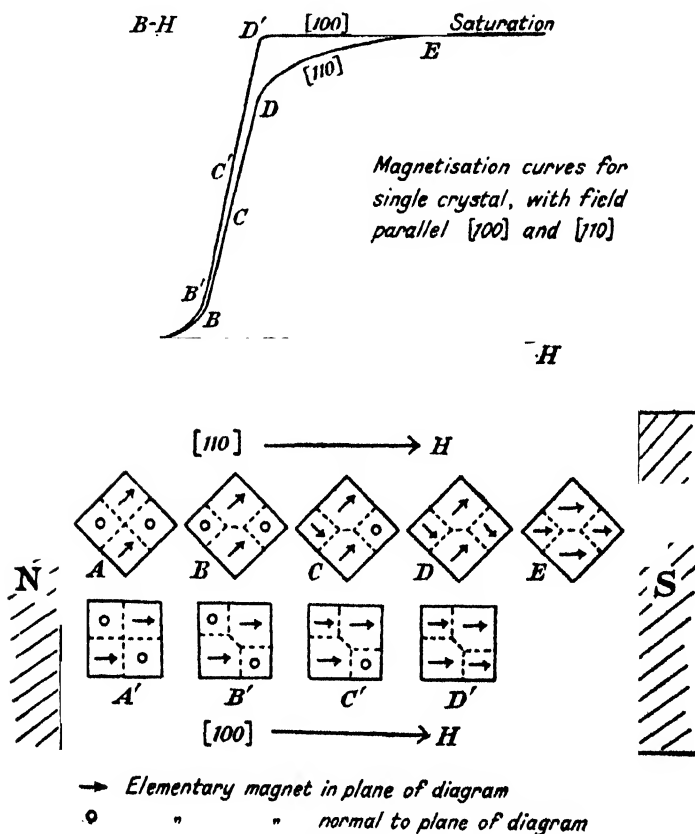


FIG. 1.

Iron, Cobalt and Nickel.—Iron crystallizes in a body-centred cubic structure at room temperatures, the work required to magnetize a single crystal to saturation being greater for $[111]$ directions than for $[110]$, and greater for $[110]$ than for $[100]$. In nickel, which is face-centred cubic, the order of increasing ease of magnetization is reversed, being $[100] \rightarrow [110] \rightarrow [111]$. Cobalt is hexagonal at room temperatures, magnetization being easy along the hexagonal axis, difficult in the basal plane.

McKeehan and his students have made a study of the Fe—Co—Ni alloys in an attempt to determine how the anisotropy constants, K_1 and K_2 , vary with chemical composition, crystal structure and temperature [40]. It is found that K_1 is not very structure-sensitive. The order of ease of magnetization can vary with temperature and alloying owing to changes in the relative values of K_1 , K_2 [41]. There are regions in which both K_1 and K_2 are very small, the alloys then being almost completely isotropic.

A summary of the various theories put forward to explain the origin and variations of K_1 , K_2 , has recently been given by Van Vleck [42].

When a rod of iron is magnetized its length increases slightly; this is one example of what is known as *magnetostriction*. The processes of cold-working can produce considerable strain in crystals, and so can phase transformations and the presence of chemical impurities. Abrupt changes in orientation of the spins in the domains may cause considerable internal strain. The direction of easy magnetization in a strain-free crystal may differ entirely from that in one which is subject to strain, and recent experiments have shown that crystals from which the random strains have been either removed or directed can attain enormous permeabilities. Single crystals of silicon-iron [18], of permalloy and of pure iron [43], which after ordinary heat treatment have been again carefully annealed *in the presence of a small magnetic field* have had permeabilities of over 1,300,000 in the direction of easy magnetization. The maximum permeabilities in less-favourable crystal directions are only one-tenth or one-hundredth of this value. A recent article by Bozarth [44] gives an excellent summary of up-to-date knowledge in this field.

Magnetite, Fe_3O_4 , the substance whose ferromagnetic properties were known so long ago, forms cubic [45] crystals in which the variation of magnetization with direction is similar to that in nickel.

Pyrrhotite, a hexagonal [45] crystal of approximate composition FeS , has one direction (normal to the hexagonal axis) in which there is normally spontaneous magnetization. The hysteresis curves for an applied field in this direction are simple rectangles, the intensity of magnetization changing sign abruptly for a coercive field of about 15 gauss. Normal to this direction and to the hexagonal axis an applied field of about 7300 gauss is needed for saturation, while parallel to the axis the crystal is virtually paramagnetic, the field required for saturation being about 150,000 gauss.

Many of the ferro-magnetic compounds have second, non-ferromagnetic forms.

REFERENCES

1. STONER, *Magnetism and Matter*, Chap. I (1934).
2. TYNDALL, *Faraday as a Discoverer*, p. 106 (1894).
3. POISSON, "Mémoire sur la Théorie de Magnétisme," *Mém. de l'Inst.*, 1821-22, Paris (1826); "Mémoire sur le Magnétisme en Mouvement," *Mém. de l'Inst.*, 1823, Paris (1827). Quoted by WM. THOMSON, see ref. 6.
4. TYNDALL, *Diamagnetism and Magnecrystalline Action*, p. 4 (1888).
5. Faraday's Diary. Edited by L. C. MARTIN, **5**, 55-148, **6**, 361-93, 409-33, 438-94 (1930).
6. THOMSON, *Phil. Mag.*, 4th series, **1**, 184 (1851).
7. GOETZ and FOCKE, *Phys. Rev.*, **38**, 1569 (1931).
8. HART, *Phys. Rev.*, **52**, 130 (1937).
9. BRAGG, *Nature*, **119** (Supplement), 72 (1927).
10. TYNDALL, *Faraday as a Discoverer*, p. 112 (1894).
11. STENGER, *Wied. Ann.*, **20**, 304 (1883); **35**, 331 (1888); KÖNIG, *ibid.*, **31**, 273 (1887).
12. KRISHNAN and BANERJEE, *Phil. Trans. Roy. Soc., A*, **235**, 343 (1936).
13. — *Phil. Trans. Roy. Soc., A*, **234**, 265 (1935); KRISHNAN and MOOKHERJI, *Phys. Rev.*, **50**, 860 (1936).
14. SUCKSMITH, *Phil. Mag.*, **8**, 158 (1929).
15. RABI, *Phys. Rev.*, **29**, 174 (1927).
16. KRISHNAN, GUHA and BANERJEE, *Phil. Trans. Roy. Soc., A*, **231**, 235 (1933); KRISHNAN and BANERJEE, *Current Science*, **3**, 548 (1935).
17. WILLIAMS, *Rev. Sci. Inst.*, **8**, 56 (1937).
18. — *Phys. Rev.*, **52**, 747 (1937).
19. PASCAL. See summary in BHATNAGAR and MATHUR, *Physical Principles and Applications of Magnetochemistry*, pp. 59-66 (1936).
20. LONSDALE and KRISHNAN, *Proc. Roy. Soc., A*, **156**, 597 (1936); LONSDALE, *Proc. Roy. Soc., A*, **159**, 149 (1937).
21. PAULING, *J. Chem. Phys.*, **4**, 673 (1936); LONSDALE, *loc. cit.*
22. LONDON, *J. Phys. Radium*, **8**, 397 (1937).
23. LONSDALE and KRISHNAN, *loc. cit.*; LONSDALE, *Nature*, **137**, 826 (1936).
24. KRISHNAN and GANGULI, *Nature*, **139**, 155 (1937); GANGULI, *Phil. Mag.*, **21**, 355 (1936).
25. HONDA, *Ann. der Physik*, **32**, 1027 (1910); OWEN, *ibid.*, **37**, 657 (1912).
26. OXLEY, *Phil. Trans. Roy. Soc., A*, **214**, 109 (1914); CABRERA and FAHLENBRACH, *Z. Phys.*, **89**, 682 (1934); BOSE, *Phil. Mag.*, **21**, 1119 (1936).
27. JONES, *Proc. Roy. Soc., A*, **147**, 396 (1934).
28. SHOENBURG and UDDIN, *Proc. Roy. Soc., A*, **156**, 687 (1936).
29. GOETZ and FOCKE, *Phys. Rev.*, **45**, 170 (1934).
30. KRISHNAN, CHAKRAVORTY and BANERJEE, *Phil. Trans. Roy. Soc., A*, **232**, 103 (1934).
31. SCHLAPP and PENNEY, *Reports on Progress in Physics*, **2**, 60 (1935), *Phys. Soc.*
32. KRISHNAN and MOOKHERJI, *Nature*, **140**, 549 (1937); PENNEY and KYNCH, *Nature*, **140**, 109 (1937).
33. COTTON and DUPOUY, *Congr. int. elect.*, **3**, 207. Paris (1932).
34. JACKSON, *Proc. Roy. Soc., A*, **140**, 695 (1933).

35. VAN VLECK, *Phys. Rev.*, **41**, 208 (1932).
36. KRISHNAN and MOOKHERJI, *Phys. Rev.*, **51**, 528, 774 (1937).
37. HOWARD, *J. Chem. Phys.*, **3**, 813 (1935).
38. BECKER, *Theorie der Elektrizität*, **2**, Chap. 4, (1933); BLOCH, *Handbuch der Radiologie*, 2nd ed., **6**, Part 2, p. 604 (1934).
39. BOZORTH and DILLINGER, *Phys. Rev.*, **35**, 733 (1930).
40. MCKEEHAN, *Phys. Rev.*, **51**, 137 (1937).
41. BOZORTH, *Phys. Rev.*, **50**, 1076 (1936).
42. VAN VLECK, *Phys. Rev.*, **52**, 1178 (1937).
43. BOZORTH, *J. Applied Physics*, **8**, 575 (1937).
44. — *Bell System Tech. J.*, **15**, 63 (1936).
45. BRAGG, *Atomic Structure of Minerals*, pp. 99, 67 (1937).

THE EXPERIMENTAL CONTROL OF THE SEX RATIO

BY ARTHUR WALTON, B.Sc., PH.D.

School of Agriculture, The University of Cambridge

SINCE the genetic theory of sex determination has become established it is clearly not profitable to discuss theories of sex determination which do not conform to established principles. There are, however, several possible ways in which sex might be controlled within the framework of genetical theory. In this paper three such possibilities are discussed. In Fig. 1 the framework of genetical theory

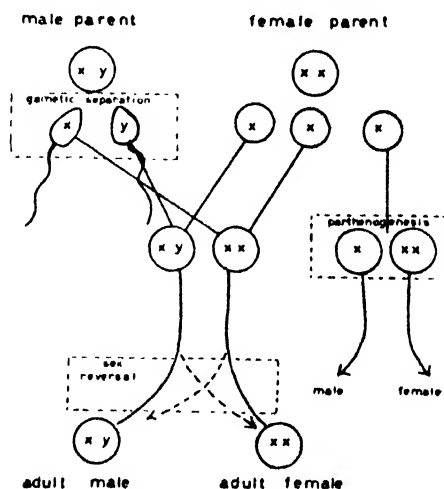


FIG. 1.

is shown for mammalian sex determination. The male parent, being digametic, produces spermatozoa of two sorts x and y , which are female and male determining respectively. The female parent produces only the one sort of egg (x). According to whether the egg is fertilised by an x or y sperm, the embryo will in the process of growth take the path of sexual differentiation in either the female or the male direction. In the diagram three possible modes of

sex control are indicated, parthenogenesis, sex reversal and gametic separation.

Parthenogenesis is a normal mode of reproduction in many invertebrates, for example in insects. It can be induced artificially in invertebrates such as the echinoderms. It has also been induced in amphibia. In mammals, however, the difficulties involved in manipulating the unfertilised ovum are very great, but noticeable progress in this direction has been made in recent years (see Pincus (1936)) and parthenogenesis to a certain stage of embryonic development has been observed. The sex of a parthenogenetic mammal is problematical. If the embryo remains haploid a male possibly would result. If, as is more likely, fusion of nuclei occurs with a return to the diploid condition a female would be formed. Although a possible mode of sex control, parthenogenesis in the mammal still offers too great difficulties to be considered practicable even in the near future.

In much the same way we may consider the question of sex control by means of sex reversal. Although the genetic mechanism determines the path which the embryo will normally take, the embryo is never so completely stabilised as to be incapable of deviation from that path. In many invertebrates sex reversal is still possible in adult life, as for example in the oyster. Abnormal sex reversal has been described in amphibia and birds, and to some extent in mammals, for example the free martin.¹ In birds considerable progress has been made in the experimental approach to the subject starting with the pioneer work of Minoura (1921) and Greenwood (1925) and the more recent experiments of Willier, Gallagher and Kock (1935), and others who have shown that sexual differentiation in the chick can be affected by injection of sex hormones into the developing egg. Similar operations on the mammalian embryo have been attempted and no doubt progress will be made, but at present sex reversal as a practical method of sex control must be regarded as visionary. It should be noted, however, that if sex reversal were complete and the animal fertile the sex ratio of the offspring of these animals would be largely affected. Thus an individual originally a female with genetic constitution xx functioning as a male would produce only female offspring. An individual originally a male with constitution xy functioning as a female would produce offspring in the ratio of 1 xx , 2 xy and 1 yy . The latter probably would be non-viable.

The third possible mode of sex control is by separation of the x and y spermatozoa. This method has great advantages over the

¹ A calf showing sex aberration.

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others in involving little or no operative interference. The technique of obtaining spermatozoa and subjecting them to experimental treatment without loss of fertilising capacity has reached a high standard of perfection. The transport of semen and its use in artificial insemination has been widely used in Russia. At Cambridge we have exchanged ram semen with Poland and bull semen with Holland. From Washington, U.S.A., bull semen has been sent to Buenos Aires—a journey which took seven days. If to the practical value of semen transport one could add that of sex control further considerable economic advantages would accrue.

A great many statistical enquiries and many experiments have been published in which a disturbance of the sex ratio has been claimed and in which separation or differential survival of the sex determining spermatozoa has been postulated. In many cases due consideration has not been given to the statistical significance of the data. Table I, kindly computed for me by Dr. Wishart, shows the deviation from equality which may be expected to occur by chance for different numbers of offspring (n) and with two probabilities $p = 0.05$ or 1 in 20 and $p = 0.01$ or 1 in 100. Examination of the table will show that only when n is large and the deviation great can results be regarded as statistically significant. For this reason many experiments carried out on a small scale can only be classified as "not proven" and requiring confirmation. In this paper I have chosen only certain experiments in which the evidence for or against sex control appears satisfactory.

TABLE I
CHANCE VARIATION IN SEX RATIO

n	s.e.	$p = 0.05$ 1 in 20.	$p = 0.01$ 1 in 100
10	1.58	8 : 2	9 : 1
20	2.24	14 : 6	15 : 5
30	2.74	20 : 10	22 : 8
40	3.16	26 : 14	28 : 12
50	3.54	31 : 19	34 : 16
100	5.00	59 : 41	62 : 38
500	11.18	271 : 229	278 : 222
1,000	15.81	530 : 470	540 : 460

Since genetic differences in spermatozoa were first established many attempts have been made to establish actual dimorphism. Zeleny and Faust (1915) first described a bimodal distribution of head-length frequencies in spermatozoa, and their findings were supported by Wodsdalek (1920), Parkes (1926) and many others.

More recent research on mature spermatozoa has, however, cast doubt on the significance of these results. Normal mature spermatozoa show little variation in head measurement and bi- or polymodality only appears in abnormal specimens (Lush (1925), Williams and Savage (1925)). However, the possibility of dimorphism following genetic constitution led to experimental attempts at separation. Lush (1925) centrifuged suspensions of rabbit spermatozoa and inseminated females with the denser and less dense portions, but obtained no difference in the sex-ratio of the offspring. In 1924 I investigated the possibility of effecting a separation by means of cataphoresis, that is to say by placing the spermatozoa in an electric current between two electrodes, but I did not reach definite conclusions. Koltzoff and Schröder (1933) and Schröder (1934) claim, however, to have had success with this method. Their fundamental assumption is that the male determining and female determining spermatozoa are differently charged so that they drift to the negative and positive poles respectively. Insemination with spermatozoa from each pole gave an excess of females or males as the case might be. The separation was, however, never complete and varied with external factors such as temperature and the nature of the medium. The actual data are few and of doubtful significance. Machowka and Schegaloff (1935) question the fundamental assumption of Schröder that the spermatozoa are differently charged. They found that all spermatozoa are negatively charged. They found, however, that in the electric current the spermatozoa are orientated towards the negative pole so that they swim in that direction, although at the same time they tend to drift towards the positive pole. If the external conditions are just right a separation can be affected between those which swim actively to the negative pole and those, less active, which drift to the positive pole, but they failed to obtain any disturbance in sex ratio. Further research on this method is clearly indicated.

Claims have also been made to control sex by means of alteration in the reaction of the vagina. Some mild alkali or acid, usually bicarbonate of soda and lactic acid, is used to wash out the vagina before copulation. This method has been advocated for human use. Schumacher (1934) criticizes this method, points out that it may possibly be harmful and could find no evidence to support the hypothesis, either from data on the human subject or in an extensive experiment with rabbits. Some data, which in collaboration with Miss Whetham I obtained (Walton and Whetham (1934)), are shown in Table II. These results also indicate no disturbance of the normal ratio.

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TABLE II

EFFECT OF ACID AND ALKALI ON SEX RATIO

	Controls Ringer sol.	Acid 0.1% Lactic.	Alkali 0.5% Na. Bic.
Total	44 : 48	41 : 44	34 : 39
Males per cent. . . .	48	48	47

One further approach to the possibility of separating the two sorts of spermatozoa is that of subjecting them to conditions in which there is differential mortality. Machowka, Jaskow and Schegaloff (1936) claim to have obtained with spermatozoa subjected to an electric field of high-frequency current a sex-ratio of 69.56 per cent. females, on a total of 368 offspring. A result which is at least formally significant. In this case it will be noted that there was an excess of females, indicating a higher mortality among the male determining spermatozoa. In Table III are shown some results obtained with rabbit spermatozoa which had been stored for various periods outside the body before insemination. In the first series (Walton (1930)) in which the spermatozoa were taken from the vas deferens there is a regular increase in the number of males. Taking each period separately the results are not highly significant, but taken as a consecutive series the probability that such a result could be due to chance is small. In this case it would appear that the female determining spermatozoa were less viable. In the second series (Hammond (1930)) the effect of storage is not definite. There is actually a slight excess of females, but not very significant.

TABLE III

SEX RATIO OF STORED SPERMATOZOA

from vas deferens

	Controls.	1st Period.	2nd Period.	3rd Period.	4th Period.
Total	295 : 290	145 : 134	178 : 170	75 : 58	28 : 16
Males per cent. . . .	50	52	54	56	63

from vagina

	Hours Stored.			
	0-24.	20-48.	50-72.	74-96
Total	155 : 153	40 : 54	69 : 76	25 : 29
Males per cent. . . .	50	43	48	46

To summarise these results on gametic separation, I think it may be said that although the majority of experiments have as yet yielded negative or doubtful results there is some evidence that under certain conditions as yet unspecified, there is a differential mortality of one or the other of the two sorts of spermatozoa. If subsequent research can elucidate these conditions sex control by means of gametic separation and artificial insemination might become practicable.

REFERENCES

- GREENWOOD, A. W. Gonad Grafts in embryonic chicks and their relation to sexual differentiation, *Brit. Jour. Exp. Biol.*, **2**, 165, 1925.
- HAMMOND, J. The effect of temperature on the survival *in vitro* of rabbit spermatozoa obtained from the vagina, *Jour. Exp. Biol.*, **7**, 201, 1930.
- KOLTZOFF, N. K., and SCHRÖDER, N. N. Artificial control of sex in the progeny of mammals, *Nature*, **131**, 329, 1933.
- LUSH, J. L. The possibility of sex control by artificial insemination with centrifugal spermatozoa, *Jour. Agric. Research*, **25**, 126, 1925.
- MACHOWKA, W. W., JASKOW, K. F., and SCHEGALOFF, S. B. *Arch. Entw. Mech.*, **135**, 282, 1936.
- and SCHEGALOFF, S. B. Die Reaktion der Spermatozoen auf konstanten Strom (Galvanotaxis), *Arch. Entw. Mech.*, **133**, 694 (footnote 694), 1935.
- MINOURA, T. A study of testis and ovary grafts on the hen's egg and their effect on the embryos, *Jour. Exp. Zool.*, **33**, 1, 1921.
- PARKES, A. S. The mammalian sex ratio, *Biol. Reviews, Proc. Cambridge Phil. Soc.*, **2**, 1, 1926.
- PINCUS, G. *The Eggs of Mammals*. Experimental monographs, New York, 1936.
- SCHRÖDER, V. N. Physico-chemical analysis of the physiology of the spermatozoon V: Artificial control of sex in mammals, *Biol. Z. (Mosk.)*, **3**, 465, 1934.
- SCHUMACHER, P. H. Theorie und Praxis der willkürlichen Geschlechtsbestimmung, *Arch. Gynäk.*, **158**, 393, 1934.
- WALTON, A. The effect of temperature on the survival *in vitro* of rabbit spermatozoa obtained from the *vas deferens*, *Jour. Exp. Biol.*, **7**, 201, 1930.
- and WHETHAM, E. O. Unpublished data, 1934.
- WILLIAMS, W. W. and SAVAGE, A. Observations on the seminal micro-pathology of bulls, *Cornell Vet.*, **15**, 353, 1925.
- WILLIIEB, B. H., GALLAGHER, T. F., and KOCK, F. C. Sex modification in the chick embryo resulting from injections of male and female hormones, *Proc. Nat. Acad. Sci. U.S.A.*, **21**, 625, 1935.
- WODSEDALEK, J. E. Studies on the cells of cattle with special reference to spermatogenesis, oögonia and sex determination, *Biol. Bull.*, **38**, 290, 1920.
- ZELNY, C., and FAUST, E. C. Size dimorphism in the spermatozoa from single testes, *Jour. Exp. Zool.*, **18**, 187, 1915.

RECENT ADVANCES IN SCIENCE

MATHEMATICS. By J. H. C. WHITEHEAD, M.A., Balliol College, Oxford.

Continuing with the foundations of the theory of abstract groups, the next set of theorems have to do with sub-groups and homomorphism (not to be confused with the topological term homeomorphism). A sub-group G_0 , of a group G is a sub-set of the elements of G which satisfies the conditions

1. If $a \in G_0$, then $a^{-1} \in G_0$ (ϵ means "is contained in").
2. If $a \in G_0$ and $b \in G_0$, then $ab \in G_0$.
3. G_0 contains at least one element.

It follows that $e \in G_0$. For G_0 contains at least one element, say a , and from the first two conditions we have $a^{-1} \in G_0$ and $(a^{-1}a) \in G_0$. Therefore the elements of G_0 , with the law of multiplication of G , themselves constitute a group. We agree that G_0 may be G itself. On the other hand G_0 may consist of the single element e .

Let G and H be given groups and let $x \rightarrow y = f(x)$ be a single-valued transformation under which each element x , of G corresponds to an element y , of H . This transformation need not have a single-valued inverse, nor need every element of H be the image of an element of G . For example $f(x)$ might be the unit element in H for every x in G . The transformation f is called a *homomorphism* if

$$f(xx') = f(x)f(x')$$

for every pair of elements x and x' in G , where $f(x)f(x')$ refers to the multiplication of H . If every element in H corresponds to at least one element in G , then f is called a homomorphism of G on H . Otherwise it is called a homomorphism in H . A homomorphism of G on H with a single-valued inverse (that is to say such that $f(x) = f(x')$ implies $x = x'$) is called an *isomorphism*, and an *automorphism* if H is the same group as G (to say that H is the same group as G means that G and H not only have the same elements but also the same "multiplication table"). A particularly important class of automorphisms are the *inner automorphisms*. Let a be a fixed element in a group and let

$$f_a(x) = axa^{-1},$$

where x is a variable element in G . Then

$$\begin{aligned} f_a(xx') &= a(xx')a^{-1} \\ &= (axa^{-1})(ax'a^{-1}) \\ &= f_a(x)f_a(x'). \end{aligned}$$

Moreover, $a^{-1}xa = a^{-1}x'a$, implies $x = a^{-1}ax'a^{-1}a = x'$, and if y is any element in G , then $a(a^{-1}ya)a^{-1} = y$. Therefore the transformation

$$y = f_a(x)$$

is an automorphism of G . Such an automorphism is called an inner automorphism. The resultant of f_a followed by f_b is given by

$$\begin{aligned} y &= f_a\{f_b(x)\} \\ &= b(axa^{-1})b^{-1} \\ &= (ba)x(a^{-1}b^{-1}). \end{aligned}$$

It is easy to verify that $a^{-1}b^{-1}$ is the inverse of ba and it follows that the inner automorphisms constitute a group. Moreover, writing $f_b f_a$ for the resultant of f_a followed by f_b , we have

$$f_b f_a = f_{ba}$$

Therefore the correspondence

$$a \rightarrow f_a = \phi(a)$$

is a homomorphism of the original group G on the group of inner automorphisms.

Let $y = f(x)$ be a homomorphism of G in H . It is easy to verify that the set of elements in H which correspond to elements in G constitute a sub-group H_0 , of H . That is to say, any homomorphism of G in H is a homomorphism of G on some sub-group of H . Clearly the function f determines a homomorphism of any sub-group of G on some sub-group of H_0 . In particular let f be an automorphism. Then each sub-group G_0 , of G , is transformed into a sub-group $f(G_0)$. Any two sub-groups are said to be *conjugate* to each other if one is transformed into the other by an inner automorphism. A sub-group which is invariant under the group of automorphisms is called a *self-conjugate* or an *invariant* sub-group. The individual elements of an invariant sub-group need not be invariant. In fact, an invariant sub-group G_0 may be defined as one which satisfies the condition $axa^{-1} \in G_0$, if $x \in G_0$, where a is any element in the original group G .

Many of the most important theorems in the theory of groups and their applications have to do with invariant sub-groups. To illustrate this let us turn back to the relation between geometry and transformation groups. Let G be any transformation group

in a space S and let ϕ be any class of figures in S . The transformations in G which leave ϕ as a whole invariant (i.e. not necessarily the individual figures in ϕ) form a group G_1 . For, using small letters to denote the transformations of G , if $a\phi = \phi$ and $b\phi = \phi$ it follows that

$$ba\phi = b\phi = \phi.$$

Similarly, the transformations which leave each figure in ϕ invariant form a sub-group G_2 of G_1 . I say that G_2 is invariant in G_1 . For let F be any figure in ϕ and a and x any transformations in G_1 and G_2 respectively. Then

$$\begin{aligned} axa^{-1}(F) &= ax(a^{-1}F) = a(a^{-1}F) \\ &= (aa^{-1})F = F, \end{aligned}$$

since $a^{-1}F \in \phi$ if $a \in G_1$ and $xF_1 = F_1$ if $F_1 \in \phi$. That is to say, $axa^{-1} \in G_2$ and G_2 is invariant in G_1 . Again, let G_1 be any transformation group in S and G_2 an invariant sub-group of G_1 . Then the property of being equivalent under the transformations of G_2 is invariant under the transformations of G_1 . For let $F' = xF$, where $x \in G_1$, and $F_1' = aF$, $F_1' = aF'$, where $a \in G_1$. Then

$$F_1' = aF' = axF = (axa^{-1})F_1,$$

and $axa^{-1} \in G_2$, since the latter is invariant in G_1 .

By way of example, let S be the projective plane, referred to homogeneous co-ordinates (x, y, z) , and let G be the projective group, given by

$$\begin{aligned} x' &= a_1x + b_1y + c_1z \\ y' &= a_2x + b_2y + c_2z \\ z' &= a_3x + b_3y + c_3z, \end{aligned}$$

where the determinant of the coefficients is unity. Let ϕ be the line $z = 0$, the "figures" in ϕ being the single points on this line. Then, using non-homogeneous co-ordinates (X, Y) , G_1 is the "affine" group, given by

$$\begin{aligned} X' &= A_1X + B_1Y + C_1 \\ Y' &= A_2X + B_2Y + C_2, \quad (A_1B_2 - A_2B_1 \neq 0), \end{aligned}$$

and G_2 is the group of translations

$$X' = X + C_1, \quad Y' = Y + C_2,$$

which, as one can verify by direct calculation, is invariant in G_1 . Two lines are equivalent under G_2 if, and only if, they are parallel. By our second proposition, the property of being parallel is invariant under G_1 .

We conclude by describing the relation between homomorphism

and the idea of an invariant sub-group. Let $x' = f(x)$ be a homomorphism of a group G on a group G' . Since

$$f(ex) = f(x) = f(e)f(x),$$

it follows that $f(e) = e'$, the unit element in G' . Also

$$f(xx^{-1}) = f(x)f(x^{-1})$$

and, since $f(xx^{-1}) = f(e) = e'$, it follows that

$$f(x^{-1}) = [f(x)]^{-1}.$$

Therefore $f(x^{-1}) = e'$ if $f(x) = e'$, and if $f(x_1) = f(x_2) = e'$ we have

$$\begin{aligned} f(x_1x_2) &= e'e' \\ &= e'. \end{aligned}$$

Therefore the set of elements in G which correspond to e' form a sub-group G_0 . Moreover, if $x \in G_0$ and $a \in G$, we have

$$\begin{aligned} f(axa^{-1}) &= f(a)e'f(a^{-1}) \\ &= e', \end{aligned}$$

since $f(a^{-1})$ is the inverse of $f(a)$. Therefore G_0 is invariant in G . It is called the *kernel* of the homomorphism f . If G_0 consists of the unit element alone (such a sub-group is invariant since $aea^{-1} = e$) f is an isomorphism. For if $f(a_1) = f(a_2)$ we have $f(a_2a_1^{-1}) = e_1$ and $a_2a_1^{-1} = e$. That is to say, $a_1 = a_2$, and f , being a homomorphism on G' , is an isomorphism.

Conversely let G_0 be any invariant sub-group of G . We define a new group, called the *factor-group* $G/G_0 = \Gamma$, say, as follows. We divide the elements of G into classes, two elements a_1 and a_2 , belonging to the same class if, and only if, $a_2a_1^{-1} \in G_0$ (this definition is independent of the ordering of a_1 and a_2 since $a_1a_2^{-1} = (a_2a_1^{-1})^{-1}$ and G_0 is a group). If $a_2a_1^{-1} \in G_0$ and $a_3a_2^{-1} \in G_0$ we have $a_3 = x_1a_1$ and $a_2 = x_2a_1 = x_2x_1a_1$, where $x_1, x_2 \in G_0$. Therefore $a_3a_1^{-1} \in G_0$, since G_0 is a group. That is to say, a_1 and a_3 belong to the same class if each belongs to the same class as a_2 . Therefore these classes are mutually exclusive, and they shall be taken as the elements of Γ . Let α_1 and α_2 be any elements in Γ and let a_1 and a_1' be any elements in α_1 and a_2 and a_2' any elements in α_2 . Let $a_1' = x_1a_1$, $a_2' = x_2a_2$. Then

$$a_1'a_2' = x_1a_1x_2a_2 = (x_1a_1x_2a_1^{-1})a_1a_2 = x_2a_1a_2$$

where $x_2 \in G_0$, since $a_1x_1a_1^{-1} \in G_0$. Therefore the elements a_1a_2 and $a_1'a_2'$ belong to the same class, which we define as the product $\alpha_1\alpha_2$ in Γ . We take the class containing e (i.e. G_0 itself) as the unit element η , in Γ . Then clearly $\eta\alpha = \alpha$, since $ea\eta\alpha$. Again, if $ae\alpha$ and $a'\epsilon\alpha$, we have $a' = xa$, where $x \in G_0$, and

$$a'^{-1} = a^{-1}x^{-1} = (a^{-1}x^{-1}a)a^{-1} = xa^{-1},$$

where $x_1 \in G_0$. Therefore the elements α^{-1} and α'^{-1} belong to the same class, which we take to be α^{-1} , the inverse of α . Clearly $\alpha^{-1}\alpha = \eta$, since $\alpha^{-1}a\epsilon\alpha^{-1}\alpha$. Therefore the elements α , with the law of multiplication so defined, form a group, the group Γ .

In the course of defining Γ we have actually proved that the transformation $\alpha = \phi(a)$, where $a\epsilon\alpha$, is a homomorphism of G on Γ , and that G_0 is the kernel of ϕ . Thus there is a homomorphism having a given invariant sub-group as its kernel. Let $y = f(x)$ be any homomorphism of G on a group H , having G_0 as its kernel. Let a_1 and a_2 be any elements in G belonging to the same element α , in G/G_0 . Then $a_2 = xa_1$, where $x \in G_0$, and $f(a_2) = f(x)f(a_1) = f(a_1)$ since $f(x)$ is the unit element in H . Therefore f_0 , defined by

$$f(a) = f_0(\alpha) \quad (a\epsilon\alpha),$$

is a singled-valued transformation of the elements of Γ into certain elements in H . If α_1 and α_2 are any elements in Γ , let $a_1\epsilon\alpha_1$ and $a_2\epsilon\alpha_2$. Then

$$\begin{aligned} f_0(\alpha_1\alpha_2) &= f(a_1a_2) = f(a_1)f(a_2) \\ &= f_0(\alpha_1)f_0(\alpha_2). \end{aligned}$$

Therefore f_0 is a homomorphism. If b is any element in H there is an $a \in G$ such that $f(a) = b$, since f is a homomorphism on H . Therefore f_0 is a homomorphism of Γ on H . Finally, if $f_0(\alpha)$ is the unit element in H , $f(a)$ is the unit element. Therefore, $a \in G_0$ and $\alpha = \eta$, the unit element in Γ . That is to say, the kernel of f_0 consists of the unit element alone and it follows that f_0 is an isomorphism. Moreover, the two homomorphisms ϕ and f are *equivalent*, in the sense that $f = f_0\phi$. For if $a\epsilon\alpha$ we have $\phi(a) = \alpha$ and, by definition, $f_0(\alpha) = f(a)$. The group Γ and the homomorphism f_0 are uniquely determined by G_0 , and the relation of equivalence between homomorphisms of G on other groups is obviously transitive. Therefore any two homomorphisms of G on other groups are equivalent if they have the same kernel.

ASTRONOMY. By R. W. WRIGLEY, M.A., F.R.S.E., Royal Observatory, Edinburgh.

THE REINMUTH ASTEROID, 1937 UB.—Asteroid hunters are continually discovering bodies which approach nearer and nearer to the earth, and, instead of being confined to the region between the orbits of Jupiter and Mars, these small bodies must now be regarded as spreading at least from the orbit of Mercury to that of Saturn. In 1932 Amor and Apollo, discovered by Delporte and Reinmuth respectively, were found to come within 10 million and 3 million miles of the earth, while in February 1936, Delporte secured a

photograph of Adonis, whose minimum distance is less than one and a half million miles. This record has again been broken by Reinmuth's latest discovery. On October 28 last, he photographed a rapidly moving object of magnitude 10, whose orbit was inclined only a few degrees to the ecliptic. Its rapid motion prevented many observations from being secured and made those that were obtained somewhat difficult to measure, so the orbit is not as yet very satisfactory. According to an ephemeris computed by Dr. Gondolatsch (*Copenhagen Circular* 701), it made its nearest approach to the earth during the evening of October 30, and its minimum distance was less than 400,000 miles. Dr. Crommelin (*Journal of the B.A.A.*, 1937, Dec.) points out that, except for ω , its orbit appears to be almost identical with that of Apollo, and he considers that, unless a satisfactory period can be deduced, it may prove equally irrecoverable in the future. There are hopes, however, that the trail, 62' in length, secured at Heidelberg with a two-hour exposure on October 28, will prove very useful in the computation of a reliable orbit. In *Copenhagen Circular*, 706, there are given elements computed by Cunningham from 12 observations made between October 25 and 29. The period is given as 2.1 years, the inclination rather over 6° , the eccentricity 0.62, and the perihelion distance 0.62. Even if this particular body, which has been named Hermes, is not recovered at its next return, it is probable that other similar small bodies belonging to the same family, which approach equally near to the earth's orbit, will be found in the near future.

The physical nature of the asteroids has been the subject of considerable discussion, and presents certain difficult problems. For example, Vesta appears to have twice the reflecting power of Juno, three times that of Pallas, and over four times that of Ceres, and yet they are all comparable in size and in distance from the sun, and, presumably, had a similar origin. Ceres has a reflecting power equal to that of the moon, Pallas resembles Mars, while Vesta seems more akin to Venus and Jupiter, whose high albedoes are generally ascribed to their extensive and dense gaseous envelopes. On no reasonable grounds can it be supposed that Vesta has been able to retain any trace of an atmosphere, and the actual surfaces of the four asteroids would naturally have been expected to be identical.

Some asteroids have been observed to show variations in brightness in the course of a few hours. Eros is remarkable in this respect, its changes being at times extensive and rapid, and at other times almost entirely non-existent. At some oppositions its brightness has shown a range of over a magnitude with a regular period of 5 hours 17 minutes, but these large variations have persisted for

only a short time. The changes have generally been ascribed to the asteroid's rotation round an axis high inclined to the ecliptic, while different areas of its surface show wide variations in reflecting power. From consideration of the light curve, H. N. Russell (*Astrophysical Journal*, **24**, 1) deduced that, given sufficient observations, the position of its equator might be ascertained, but the sign of the inclination and the actual shape of the body would remain indeterminate.

At Johannesburg in February 1931, Van den Bos and Finsen, using a power of 1070 on the 26-inch refractor, found the image of Eros to be a definite figure-of-eight, resembling that of a "notched" or nearly separated double star of about $0''.18$ distance. The position angle of the components was measured over a period of $5\frac{1}{2}$ hours, and was found to make a complete revolution in a period of 5 hours 17 minutes, showing good agreement with the photometric period. The full list of observations is given in *Ast. Nach.* 5780.

A more complete investigation is described by Fletcher Watson in *Harvard Circular* 419. The earliest available observations date from 1893, but the useful series commence in January 1901. Assuming that the maximum variation in brightness, whether it be caused by eclipses or by surface spots, will appear when the earth lies in the equatorial plane of Eros, it is found to occur when the latter is near the celestial great circle whose pole is situated at R.A. 316° , Dec. $+51^\circ$. The north pole of its axis of rotation must, therefore, point in this direction, for the range of its light variation is shown to be directly related to its distance from the great circle. The rotation of Eros is found to be retrograde, the inclination of its equator to the ecliptic is $152^\circ.5$, and to the plane of its orbit is 146° .

Watson considers the existence of a "double asteroid" to be most improbable in view of their supposedly catastrophic origin and consequently fragmentary nature. He interprets the Johannesburg observations as indicating Eros to be a long irregular solid of length about 35 km. and diameter 11 km., possessing a reflectivity of about 0.15, and a colour index of about $+0.80$ mag. There is no apparent relation between the colour index and the phase of rotation. The rotation is about an axis perpendicular to the longest dimension of the asteroid, which, on the assumption of a density of 3.5, has a mass about 2×10^{-9} that of the earth.

That considerable uncertainty attaches to these figures is shown by the following comparison of the various positions of the north pole obtained by different investigations :

W. Zessewitech	R.A. 18°	Dec. + 31°
J. Rosenhagen	342°	+ 42°
Krug and Rechtenstamm.	333°	+ 48°
Watson	316°	+ 51°

These remarkable differences suggest that the direction of the rotation axis of Eros must be subject to considerable change, and this view is supported by Zessewitsch (*Observatory*, 1937, Nov.). Accurate and consecutive light curves obtained for as long periods as possible with ordinary telescopes, together with observations of the asteroid's size and shape, and the direction of its elongation, possible only with very large instruments, are now needed. Then, in the words of Watson, "Eros, which has been the enigma of the asteroids, may lead to a better knowledge of their physical nature, and possibly of their mode of origin."

In view of Watson's summary rejection of the idea of a "double asteroid," it is interesting to find that the next *Harvard Circular* (420) is devoted to an account of Cosmic Double Meteors, by Dorrit Hoffleit. The existence of these systems, governed by their mutual gravitational attractions, is inferred from the simultaneous appearances of small numbers of meteors, and from certain close double trails found on meteor photographs. Miss Hoffleit, using a mathematical analysis due to E. Öpik, calculates the effect of stellar perturbations on double meteors, finding that nearly all the pairs originally separated by less than 6 km. have remained physical pairs during the life of the universe, while, of those whose separations exceeded 50 km., practically none can remain as binary systems. Observational data of naked eye sporadic meteors appearing within ten seconds of each other yielded inconclusive results, but an analysis of telescopic observations, using a field 45 minutes in diameter, indicated that 16 per cent. of the tenth magnitude bodies were members of binary systems, with a separation of about 20 metres. Such close pairs will have suffered practically no disruptions during the existence of the universe, so that 16 per cent. represents the original proportion. On the assumption that this proportion originally applied to all cosmic meteors, Miss Hoffleit estimates that approximately 3 per cent. of present naked eye observations of sporadic meteors should represent real double meteors.

PLANETARY ATMOSPHERES.—Estimates of the temperature of planetary atmospheres have generally been obtained by determining the distribution of energy in the reflection and emission spectra of the planets, but it has proved difficult to eliminate com-

pletely the effects of the earth's atmosphere. In the *Astrophysical Journal*, **86**, 3, A. Adel proposes a more independent method, depending on the fact that, in a planetary atmosphere, the distribution of molecular population over the various vibrational and rotational states is strictly determined by the prevailing temperatures. Consequently, the distribution of intensity of absorption in the fine structure of the bands is also governed by the temperature, of which it is, in most instances, a simple function.

Definitive high-dispersion spectra, such as are necessary to make possible the unambiguous selection of the fine structure lines displaying the maximum intensity of absorption, are not yet available, but Adel illustrates his method on a spectrum of Venus obtained at Mount Wilson by Adams and Dunham. This shows two carbon dioxide absorption bands, each possessing a converging high-frequency branch and a diverging low-frequency branch. The latter are more convenient for study, and the distribution of intensity of absorption indicates that the temperature of 50°C ., calculated by D. H. Menzel from water-cell transmissions, is probably too low a value for the surface of Venus.

The opposition of Mars in 1937 was utilised at Mount Wilson by Adams and Dunham for a further search for water vapour lines in its spectrum (*Publ. Ast. Soc. Pacific*, **49**, 209). The spectrograms, covering the region about λ 7200, were obtained with a plane grating spectrograph of 9 feet focal length at the coudé focus of the 100-inch reflector, and gave a scale in the first order of 6 Å. to the millimetre. Two spectrograms were secured in February when Mars was approaching the earth with a velocity of 19 km./sec., corresponding to a displacement of 0.45 Å., and the water vapour lines due to the planet's atmosphere should therefore have been completely separated from those of terrestrial origin. One spectrogram, obtained in April when Mars was approaching with a velocity of 11 km./sec., should have shown the planetary lines as a fringe on the violet side of the terrestrial ones. In no case, however, could evidence be found of the presence of any water vapour in the atmosphere of Mars, and it seems that the intensities of any lines cannot exceed 5 per cent. of those of the corresponding terrestrial ones, and are probably much less. The observations were all made near the centre of the planet's disc, and it would be interesting, at a future opposition, to see if similar negative results would be obtained over the polar caps. Whether these are actual masses of snow and ice or are largely cloud effects, it is in their neighbourhood that water vapour might be expected to be most in evidence.

The important part that photochemical processes play in

planetary atmospheres, and the constituents of the latter which can be postulated by chemical arguments even if they are not directly detectable by the spectroscope, are considered by Rupert Wildt in *Astrophysical Journal*, **86**, 3. It is necessary first to explain how a stationary state can be maintained in atmospheres containing such polyatomic molecules as those of carbon dioxide, methane, and ammonia, which are highly susceptible to decomposition by ultra-violet solar radiation. Their photochemical decomposition must be followed by secondary chemical reactions, reuniting the products of dissociation, in order to maintain the observed stationary composition of the atmospheres.

Regarding the giant planets, Wildt shows that the stability of methane can be reasonably explained. During the comparatively slow processes of decomposition and recombination, atoms of hydrogen must exist in the atmospheres in considerable abundance, and these are known to attack and break up all hydrocarbons with the exception of methane. This explains the absence of other simple hydrocarbons which have vapour tensions only slightly smaller than that of methane, and therefore could not possibly be frozen out completely. In addition, it is shown that carbon monoxide, carbon dioxide and hydrogen sulphide are all probably absent, the last being disintegrated and solid sulphur precipitated. This is all satisfactorily in agreement with spectroscopic observations. The stability of ammonia in the atmosphere of Jupiter cannot, however, yet be satisfactorily explained by photochemical theory.

Of recent years, following the work of H. Jeffreys, Jupiter has generally been regarded as a cold body, with surface temperature not exceeding 150° Absolute, covered with a thick layer of ice, and surrounded by a dense atmosphere more than 6000 km. deep. In *Monthly Notices R.A.S.*, **97**, 8, B. M. Peek gives reasons why such an extensive atmosphere cannot exist, for "either the temperature must rise with the depth at a rate that will certainly not admit of the interior being regarded as cold, or the pressure, at quite surprisingly small depths, becomes so great that, even if the gases do not liquefy on account of their low critical temperatures, the density becomes equal to that of their liquid or solid states." He proceeds to investigate the depth, pressure, temperature and density in Jupiter's atmosphere assuming three different models, (1) where the pressure, density and temperature obey the ordinary adiabatic laws, (2) an isothermal atmosphere, and (3) a compromise between the two.

For the purpose of numerical evaluation in the first two models,

the atmosphere is assumed to be composed entirely of methane. For the third model three separate calculations are made assuming (1) an atmosphere of pure methane, (2) a mixture of hydrogen and methane in the proportion of 3 parts to 4, and (3) a proportion of 6 parts to 1. Pressure-depth curves are drawn, showing in each case the depths at which the gases would reach the solid state. For all the models great densities are found to be rapidly attained, and, even under the most favourable circumstances, it appears that the atmosphere of Jupiter cannot extend to more than a fraction of 1 per cent. of the radius of the planet. At a depth of only 25 km. it must lose all its familiar characteristics owing to the gases undergoing a change of state. Mr. Peek points out that the idea of irregular opacity at high altitudes in the Jovian atmosphere, put forward by R. A. Sampson to explain certain differences between the predictions of his tables and the observed times of occasional satellite phenomena, now becomes untenable, and the true explanation of the discrepancies will have to be sought elsewhere.

PLANET PHOTOGRAPHY.—Considerable work has been done in America, and, to a less degree, in Germany in connection with photography of the surface details of the planets, but in this country, probably owing to handicaps of climate and of latitude, the subject has received little attention. A recent publication (in German), *Planeten-Photographie*, von Dr. H. J. Gramatzki (Berlin und Bonn : Ferd. Dümmler, 1937. RM. 2.70) will be found very useful by anyone wishing to undertake this branch of research. In its 71 pages the author discusses the most suitable form of instrument, the technique of observation necessary to eliminate the worst effects of atmospheric disturbance, the use of light filters and special plate emulsions, and the photometric treatment of the results. It is found that for this type of work, requiring a focal length of at least 5 metres, large Cassegrain reflectors like the 100-inch, and also Schmidt telescopes are decidedly inferior to the Newtonian type, used in conjunction with a Barlow lens. The fitting of a reflex camera, by means of which the moments of good definition can be noted and utilised, is strongly recommended.

PHYSICS. By F. A. VICK, Ph.D., University College, London.

THE RESISTANCE OF THIN FILMS.—The more usual methods of preparing thin metallic films on non-conducting substrates are (i) by condensation from metallic vapours in a high vacuum, including deposition from molecular beams, (ii) by sputtering from a cathode of the metal in a gas pressure of the order of 0.1 mm. of mercury. Until recently the many papers on the electrical resistance of such

films showed wide divergence of results, even between those obtained by the same worker. In consequence, a number of hypotheses have been put forward to account for the observations. In general, it appeared that, for films deposited in a moderate vacuum, (a) the resistivity when the thickness is less than 100 Å. is from 10^3 to 10^7 times that of the metal in bulk, (b) heating after deposition alters irreversibly the resistivity by a factor of ten or more, (c) the conductivity is detectable only when the thickness exceeds 40 Å., with a temperature of deposition about 300° K. (Bartlett, *Phil. Mag.*, **5**, 848, 1928; Reinders and Hamburger, *Rec. Trav. Chim. Pays-Bas*, **50**, 441, 1931).

The position has been made much clearer by experiments carried out recently at Bristol by Lovell and Appleyard (*Proc. Roy. Soc.*, **A**, **157**, 311, 1936; **158**, 718, 1937; *Proc. Phys. Soc.*, **49**, 89, 1937), and described by the latter at the Conference on "Conduction of Electricity in Solids" (*Proc. Phys. Soc.*, **49**, No. 274, Aug. 1937). Their work with alkali metals on pyrex glass shows the necessity of very careful outgassing of the pyrex surface before deposition, as well as keeping the residual gas pressure as low as possible. Molecules of rubidium, potassium or caesium from a beam, suitably defined by slits, fell at known rates on to a pyrex surface which could be held at temperatures between 64° K. and 90° K. Here they formed a square patch which overlapped contacts of colloidal graphite spread upon a layer of platinum which had previously been baked into the glass. A continuous series of measurements was made during and after deposition. During the preliminary experiments with rubidium, the resistivities of films prepared under apparently similar conditions varied by factors of several hundreds. It was found, however, that if the pyrex substrate was very carefully outgassed before deposition upon it, the values were consistent to within 3 per cent., enabling the following results to be obtained.

The resistivity of the films fell steadily as the thickness of the layer increased, but on stopping the deposition the resistance rose smoothly by a factor of about 10 (at 90° K.). For films of the same nominal thickness¹ deposited at the same rate, both the resistance and rate of decay of conductivity were lowest at the lowest temperatures of the pyrex. At a given temperature, the rate of decay of conductivity diminished as the thickness of the film increased. By deposition at 64° K., it was possible to prepare completely stable

¹ The nominal thickness of a film is here that calculated from $t = m/\rho$, where m is the mass per unit area. It coincides with the geometrical thickness only when the film is uniform and has the same density as the bulk metal. m is calculated from the rate of deposition from the molecular beam.

films provided the nominal thickness exceeded 40 Å. These films remained stable when afterwards raised to 90° K., though a film of this thickness deposited at 90° K. decayed in conductivity rather quickly. Results for potassium and caesium were substantially the same. Caesium films 40 Å. thick deposited at 64° K. had a resistivity only five times that of the metal in bulk, and conductivity was first detected at less than 1 Å.

The theory put forward to account for these results (and in so doing for most of the results of previous workers) may be expressed simply as follows. A metal atom deposited on a clean pyrex surface is subjected to two main forces of attraction, (a) to the glass surface, (b) to other metal atoms on the surface. The character of the metal film depends largely on which of these two forces is the stronger and whether the metal atoms can migrate along the surface.

Lennard-Jones (*Trans. Far. Soc.*, 28, 333, 1932) describes the potential distribution of the attracting field at the surface of a solid as a series of hills and hollows with a periodicity corresponding to that of the underlying lattice. At low temperatures, adsorbed atoms vibrate in the hollows of minimum potential energy, but as the temperature of the solid is raised, the probability increases that the atom will receive sufficient energy to surmount the potential hill between one minimum and the next, and if it retains that energy will migrate freely over the surface. This energy is generally known as the "Energy of Activation" (or "Heat of Activation") A , and appears to be of the order of one-quarter of L , the energy for evaporation of the adsorbed atoms from the surface ("Heat of Evaporation"). A and L depend upon both the nature of the surface and of the adsorbed atom, while L is a measure of force (a). Now let us suppose that for a particular surface and metal, the attractive force (a) between metal atom and surface is less than (b) between the metal atoms in the film. At very low temperatures the adsorbed atoms will not have sufficient energy to migrate, and a continuous film will be formed by deposition, having resistance approaching that of the bulk metal. If the film is quite uniform it will remain so when the temperature is raised, but if there are small imperfections (*e.g.* due to patches of stray gas atoms or cracks in the substrate) as soon as the temperature becomes high enough for the metal atoms to migrate, the stronger force (b) will result in the imperfections becoming more pronounced by the formation of clusters of metal atoms, with gaps between the clusters, and the resistance will increase. If the temperature at which deposition takes place is sufficiently high for a large proportion of the atoms to become "activated," island patches of the metal will readily

be formed, increasing in thickness by the deposition of more atoms on top of them and by migration on the surface. There can be practically no conductivity until these patches are large enough to touch, when the resistivity will soon approach that of the bulk metal. An intermediate case will occur when attractive force (a) is not much less than (b) and the temperature is fairly low. The migration will be slow and it will be possible for the rate of deposition of atoms to be large enough to fill in the gaps as soon as they appear and so form a reasonably coherent film. But as soon as the deposition is stopped the resistance will rise because the migration continues to help aggregation of the metal atoms. The rapidity of this decay of conductivity will be greater at higher temperatures and less for thick films. Films which agglomerate in their early stages probably have a fine crystalline structure. All this is in satisfactory accord with the experiments quoted above, though much requires to be done before the details can be filled in. Suggestions have been put forward to account for the resistivity of the thin films prepared under the best conditions being still 2-5 times that of the metal in bulk. The effect of the shortening of the mean free paths of the conduction electrons by collisions with the boundaries of the film has been examined by K. Fuchs (*Proc. Camb. Phil. Soc.*, **34**, 100, Jan. 1938).

If a layer of gas atoms is already on the pyrex surface before deposition begins, the force of attraction (a) may be reduced considerably, and with it the energy of activation. Migration and aggregation will then be very fast, even at the lowest temperatures so far used, and the resistance of the films will be correspondingly high, especially if there is also appreciable residual gas in the apparatus. The gas pressure needed for the formation of sputtered films is inevitably comparatively high, and Andrade and Martindale (*Phil. Trans.*, **235**, 69, 1935) have shown how complicated the process may be. It must be remembered too that even in a high vacuum (10^{-8} mm. Hg.) the number of gas atoms striking a surface per second is quite comparable with the number of metal atoms from a molecular ray beam.

In the same Conference Report, Lennard-Jones discusses from the theoretical standpoint the critical phenomena in films and migration along the surface. G. I. Finch shows the utility of electron diffraction in the study of such films and points out that sputtered and evaporated metallic films are invariably found to be crystalline.

THE VELOCITY OF LIGHT.—A determination of any velocity consists fundamentally of a measurement of the time taken to

traverse a known distance. In the case of light it is necessary to make some identifying mark on the beam, or to interrupt the beam in some way. Rotating mirrors or cog-wheels have been used in the past (e.g. Michelson, Pease and Pearson, *Astrophys. J.*, **82**, 26, 1935), and because of the low frequency with which the pulses occurred, large distances were necessary, with all the associated drawbacks. Karolus and Mittelstaedt showed, however (*Phys. Zeits.*, **29**, 698, 1928), that it is quite feasible to produce by means of the Kerr Cell very high frequency variations in light intensity, enabling a velocity determination to be made with a considerably shorter distance. W. C. Anderson has recently published an account of further developments in this interesting method (*Rev. Sci. Instr.*, **8**, 239, July 1937).

It will be recalled that the Kerr Cell consists essentially of two parallel metal electrodes immersed in nitrobenzene or similar liquid contained in a glass cell with plane windows, so that a beam of plane-polarised light can pass through the liquid between the electrodes. When a high voltage is applied to the electrodes, the cell behaves like a uniaxial crystal with its optic axis parallel to the electric field, and hence changes the plane-polarised beam into an elliptically polarised one, by introducing a phase difference between the components parallel and perpendicular to the electric field. This lag, δ , is proportional to the square of the electric field strength. When the cell is placed between crossed Nicols oriented so that the light incident on the cell is plane polarised at 45° to the direction of the electric field, the intensity of the beam emerging from the analyser is given by

$$J = J_0 \sin^2 (\delta/2) \quad . \quad . \quad . \quad (1)$$

where $\delta = 2 \pi B l E^2$, E = electric field intensity in e.s.u., B = Kerr constant, l cm. = length of electrodes in the direction of the light beam. The intensity is thus a periodic function of the applied voltage, and from equation (1) the first maximum is at

$$V_{\max.} = 300d/\sqrt{2Bl} \text{ volts} \quad . \quad . \quad . \quad (2)$$

where d is the distance between the electrodes. For a typical cell $l = 2$ cm., $d = 0.4$ cm., $B = 30 \times 10^{-6}$ (nitrobenzene) giving $V_{\max.} = 10,000$ volts approximately. If a steady voltage V of about 7000 is applied to the cell, changes of intensity over a limited range are very nearly proportional to V , since a plot of equation (1) is very nearly linear here. If, therefore, a sinusoidal voltage of high frequency f and moderate amplitude is superimposed on the steady 7000 volts, the intensity of the beam emerging from the

analysing Nicol will vary approximately sinusoidally at this frequency.

The frequencies used in Anderson's experiments were 14, 28 and 56×10^6 cycles per sec., generated by a crystal-controlled valve oscillator which is loosely coupled to an inductance in the Kerr Cell circuit. This circuit (Fig. 1) consists simply of a condenser and the inductance in series with the cell, the steady high voltage

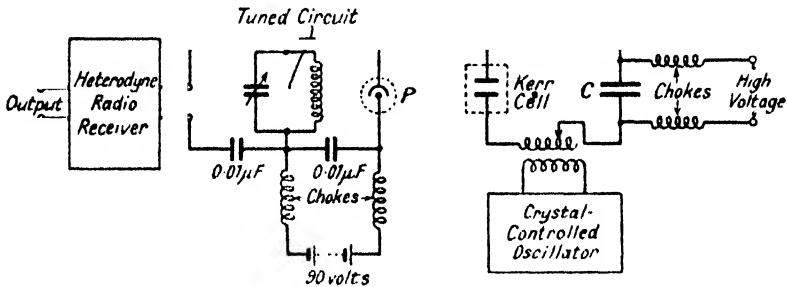


FIG. 1.

being applied across the condenser (through high-frequency chokes to prevent the radio-frequency current from leaking away instead of going through the condenser). The circuit can be tuned to resonance by varying the inductance. The frequency (which may be a harmonic of the fundamental crystal frequency) can be determined to less than one part in 10^6 by the usual methods, and is

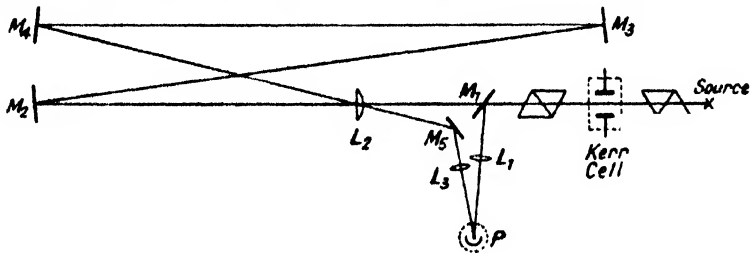


FIG. 2.

steady within these limits if the temperature control is adequate. The Kerr cell is surrounded by a water jacket.

The light, thus modulated at a known high frequency, is split into two beams at a half-silvered mirror M_1 (Fig. 2). One beam is focussed by a lens L_1 on to a vacuum photoelectric cell, the other, after passing through M_1 , is focussed by a lens L_2 (of 10 metres focal length) on to a mirror M_2 , after reflection through nearly 180° by a mirror M_3 . After similar reflection from a mirror M_4 , the beam passes again through the lens L_1 , is reflected by a mirror M_1 , and

brought to focus by lens L_2 on the same photoelectric cell, P. M_1 , M_2 and M_3 are 8-inch or 9-inch plane mirrors coated with aluminium, M_1 and M_2 being fixed on concrete pillars while M_3 is mounted on a lathe bed so that it can be moved parallel to itself. The photoelectric cell P is connected to a circuit tuned to the frequency of light modulation (Fig. 1). The radio frequency voltage developed across the tuning coil is made the input of a sensitive radio receiver incorporating a radio frequency oscillator to produce an audio frequency beat note. In general there will be a difference of phase, ϕ , between the radio frequency voltages produced across the tuning-coil by the two light beams falling on the photocell, owing to the difference in paths. If the path difference amounts to an odd multiple of half-wave lengths (of the radio-frequency modulation) then the net voltage across the tuning-coil will be a minimum, shown by the sound in telephones or deflection of a meter in the output of the radio receiver. In this case it is easily seen that

$$\phi = \frac{2\pi fs}{c} = n\pi$$

where $n = 1, 3, 5 \dots$, s cm. = optical path difference, c is the velocity of light in cm. per sec. and f the frequency of modulation.

The general procedure is therefore as follows. The cooling system of the Kerr cell is turned on and the high voltage, light source (Point-O-lite) and oscillator left running, until a steady temperature is attained. The radio receiver is tuned in to the high-frequency voltage developed by the two light beams striking the photocell, and the beams matched in intensity by means of a diaphragm across the stronger. The lathe screw is rotated and the reading of the radio receiver output plotted against the position of M_3 . From the sharp minimum in the curve the distance s is calculated. The frequency f is already known from the determination of the fundamental frequency of the quartz oscillator.

Anderson tried also a modification of the method, in which both a low- and a high-frequency modulation is imposed upon the light. This gives rise to audio-frequency components after detection by the radio receiver without using a second (heterodyne) oscillator. An audio-frequency output is desirable because of the greater ease of measurement.

The mean path difference was found to be $s = 15,934.78 \pm 0.60$ cm. for a frequency $f = 14,105,120 \pm 160$ cycles per sec., giving the velocity of light in air as 299,683 km. per sec. and *in vacuo* as $299,764 \pm 15$ km. per sec. This is the mean of 651 observations spread over a period of six months, and no secular variations outside

the experimental error were found. Michelson, Pease and Pearson (*loc. cit.*) give the velocity *in vacuo* as $299,774 \pm 11$ km. per sec.

There seems no reason why an accuracy appreciably better than that in Michelson, Pease and Pearson's experiments should not be attained with the Kerr cell method. There are several improvements which could be made in the details of the apparatus, such as precise temperature control, automatic recording of the output of the radio receiver together with lathe mirror position, and so on.

METEOROLOGY. By E. V. NEWNHAM, B.Sc., Meteorological Office, London.

THE FORMATION OF HAILSTONES.—There is a limit to the possible size of raindrops, for although the upward velocity of rising currents of air has no sharply defined limit, and the stronger the current the greater is the mass that it can support, when the speed of the drop relative to the air reaches a certain value the drop breaks up into smaller fragments. For the hailstone no such limit of growth exists, and when unusual circumstances are associated with quite exceptionally strong upward currents hailstones may, if other conditions are favourable, grow to a phenomenal size and eventually fall to earth with destructive violence when the vertical currents fail or become less than the speed of the stone relative to the air—a speed which increases with the growth of the stone. The generally accepted theory of the physical process of growth rests upon the observation that many clouds are composed of water droplets far below the ordinary freezing-point of water and that such droplets freeze very readily on striking a solid object. Given a small nucleus of ice among a cloud of supercooled water droplets, according to the theory this nucleus will encounter and gather to itself some of these droplets from time to time, and as they freeze, these increase the mass of the ice. The structure of a hailstone is consistent with this theory, suggesting as it does that successive thin layers of water have been frozen on it, a good deal of air being entrapped in the process, so giving the stone its characteristic whiteness. For stones of the usual size, up to say a quarter of an inch in diameter, the theory makes no undue demands on human credulity. At rare intervals, however, as stated above, the diameter is much larger. A number of photographs testify to instances where it has ranged from 1 to 2 inches and Bilham [1] refers to a case of a storm in Northamptonshire in September 1935 in which a hole more than 4 inches in diameter was made in an asbestos cement roof. Another case is cited by the same writer which is

still more remarkable—that of a stone 5·4 inches in diameter which fell in the Nebraska hailstorm of July 6, 1928. Wegener [2] puts the upper limit of known size as about that of a skittle ball, the weight being about 1 kg. Such instances make it desirable to consider the theory more closely in order to see whether it can include them, and have led Schumann [3] to a mathematical analysis of the physical processes involved, an account of which was given to the Royal Meteorological Society last November.

Schumann begins with certain simplifying assumptions without which the mathematical treatment would be impossibly difficult. He assumes that the stone remains spherical throughout its life history and that it collects all the water-drops in the volume that it sweeps out so long as the temperature is below 0° C. On this basis, it may be noted, Trabert in 1899 [4] calculated that, if the maximum amount of suspended water per cubic metre is 4 grm. and the total distance fallen through in the cloud is 2 km., the hailstone would not exceed 5 mm. in diameter, and was led to postulate electrical attraction between the stone and the water drops to account for the greater size actually observed, but as his theory ignores the shortness of time during which the stone is sufficiently near to a particular drop for forces of attraction to become effective, it need not be considered further here, the more so as it will presently be seen that the larger size of stone actually observed can be accounted for without its aid.

Schumann derives a number of equations connecting the ultimate size of the hailstone with the different factors upon which it depends, *e.g.*

$$mS = \sigma(4R - 1) \quad . \quad . \quad . \quad . \quad (1)$$

where m = concentration of liquid water in the atmosphere, in gram./c.c.,

S = total distance travelled by the stone relative to the surrounding air in cm.,

σ = average density of the stone (grm./c.c.),

R = ultimate radius of the stone in cm. ;

$$\text{also} \quad 100 \, mt = (\sigma\rho)^{\frac{1}{2}}(4R^{\frac{1}{2}} - 2) \quad . \quad . \quad . \quad . \quad (2)$$

where t is the time in sec. required for the formation of the stone ρ the specific gravity of air with respect to air at 0° C. and 1000 mb. pressure, and the other quantities are as previously defined. In the next stage he postulates atmospheric conditions favourable for the formation of hail, and assumes that such are provided by an air mass initially at 25° C., and relative humidity 60 per cent., which is raised by convection to any desired height. Given that

the cooling, due to reduction of pressure as the mass rises, takes place adiabatically, values of pressure, temperature and density can readily be calculated for the different heights reached. The ultimate size of the hailstone is dependent upon H , the initial height of the small hailstone, on u , the average upward velocity of the air and on m and σ . The author adopts the following plan: He calculates from the equations already arrived at certain combinations of these four quantities that will lead to the formation of very large hailstones—actually 8 cm. in diameter—and then examines the possibility that such values of the four variables may occur in nature. The first case considered is of $H = 7$ km., $\sigma = 0.6$ and L , the vertical distance travelled by the stone during its period of growth, 3 km., for which he finds what values of $m \times 10^6$ result from different values of u to give $R = 4$ cm., and gets the following:

u cm./sec.	0	500	1000	1500	2000
$m \times 10^6$	30	24.3	18.7	13.0	7.4

The process is repeated for other combinations, namely:

Case II: $H = 7$ km.	$L = 3$ km.	$\sigma = 0.8$
„ III: $H = 9$ „	$L = 5$ „	$\sigma = 0.6$
„ IV: $H = 9$ „	$L = 5$ „	$\sigma = 0.8$

The final results of these four investigations are given in the form of graphs which show four straight lines connecting u and $m \times 10^6$ under each of the four conditions laid down. Cases I and II differ only in regard to the density of the stones, and similarly with III and IV. In case III the hypothetical heights are great and the density of the stone small, consequently less abnormal values of u and $m \times 10^6$ are required to produce the 8 cm. diameter stone than in the other three cases. The graph shows that for $u = 0$ $m \times 10^6$ need not then exceed about 16, and for $u \times 2000$ cm./sec. just over 5. On the other hand, in case II where the heights are smaller and the stones heavier, the corresponding values of $m \times 10^6$ are 40 and 14, i.e. between two and three times as great. These figures show that the conditions necessary for the formation of abnormally large stones are that the cumulo-nimbus clouds must extend to great heights and that in addition there must be either an extraordinarily great concentration of water-drops or extremely violent and long-lasting upward currents of air. The answer to the question whether m and u can reasonably be expected to attain to such values requires more careful examination before it can be

answered, and the author deals first with another matter that should be taken into account, namely the question of the disposal of the latent heat of condensation of the water, which heat is set free when freezing occurs and may be expected to have some influence on the rate of growth of the stone unless the temperature is far below the freezing-point. Setting aside the amount of heat that may be used in raising the temperature of the stone when the latter is below 0°C. as too small to be of any importance the author has to fall back upon conduction to the surrounding atmosphere and the latent heat absorbed if part of the water is evaporated. It is generally accepted that a thin film of stagnant air surrounds a solid object even when the atmosphere around is in turbulent motion. If the thickness of the film around a hailstone is denoted by B , and the heat conducted away per second by h_1 , then

$h_1 = 4\pi r^2 K \frac{\theta}{B}$, θ being the difference between the temperature of the surface of the stone and that of the air, and K the thermal conductivity of the air in c.g.s. Centigrade units. For every gramme of water that is condensed on the stone the latent heat liberated, is equal to $\lambda_1 - \theta$ calories, where λ_1 = the latent heat of fusion of ice, consequently the amount liberated per second, which we may denote by h_2 , is given by the equation $h_2 = \pi r^2 m v (\lambda_1 - \theta)$. Finally it is shown that the heat dissipated by evaporation (h_3) is given by the equation $h_3 = \frac{4\pi r^2 \times \delta \times \lambda_2 (C_1 - C_2)}{B}$

where δ = the diffusivity of the air,

λ_2 = the latent heat of vaporisation of the water,

C_1 = mass of water vapour in gm./c.c. of saturated air at the temperature of the hailstone,

C_2 = the same quantity for the surrounding air.

Clearly the heat liberated by the condensation must equal the sum of the quantities of heat lost by conduction and evaporation, so that $h_2 = h_1 + h_3$ from which it follows that

$$m v (\lambda_1 - \theta) = \frac{4}{B} \{ (K\theta + \delta \lambda_2 (C_1 - C_2)) \} \quad . \quad . \quad (3)$$

The author was not aware of any experimental determination of B that would apply to the case of the hailstone, and derived a value from theoretical considerations equal to $\frac{3\mu v}{r\sigma g}$, where μ is the coefficient of viscosity of the air and g is the acceleration of gravity. Substituting this in equation (3) we get

$$m(79.7 + 0.46T_1 - T_2) = 1.015 \times 10^{-4} \rho (T_2 - T_1) + (247 - 0.28T_1)(C_1 - C_2) \quad . \quad . \quad (4)$$

where T_1 and T_2 are the numbers of degrees of the temperatures of the stone and air respectively below 0°C . Equation (4) can readily be solved for different values of ρ and T_2 and it is found that there is a limit to the possible magnitude of m when $T_1 = 0^\circ\text{C}$., which is obtained by putting $T_1 = 0^\circ\text{C}$. in equation (4).

When m exceeds this limit not all the water captured by the stone can freeze, and some will presumably be lost by being carried off in the form of droplets by the wind represented by the relative velocity between the stone and the air (v). Using the values of T_2 and ρ calculated for different heights in the adiabatically rising air which has been already postulated, it is found that the limiting value of $10^6 \times m$ varies from 0 at 4 km. to 20.9 at 6 km. and 77.3 at 9 km., which shows how the power of the stone to collect water-drops decreases with diminishing height. This last discussion leads to the conclusion that the values of m needed to account for stones of 8 cm. diameter, which have been worked out for four different values of H , L and σ , need revision, in order to allow for the fact that below about 6 km. all the water encountered cannot be retained. The point next discussed was the possible loss of weight due to evaporation. The conclusion reached was that this is very small compared with the gain from condensation. Another matter that was successfully disposed of was the low temperature of freshly fallen hailstones sometimes observed. When account is taken of the time of fall of a large stone and its thermal conductivity, it is easily seen that the interior may be much colder than the surface, and the observation of stones with mean temperature well below 0°C . is not inconsistent with their having had a surface temperature of 0°C . during a large part of their sojourn in the upper atmosphere.

The author comes back finally to the consideration as to whether values of m and u required by theory can reasonably be expected in nature. If m were due simply to condensation taking place in a single sample of rising air, such as the one postulated here, the answer would be "no" as regards m , for it can be shown that $10^6 \times m$ would not exceed 6 or 7. But there is held to be strong evidence that a far greater accumulation can take place in clouds. An upward current of 8 m/sec. or over, which is the terminal velocity of the largest drops, will keep all condensed water in suspension and accumulation from fresh supplies of air can continue indefinitely so long as this upward current lasts. Although we lack direct measurements of values of u of the order of magnitude required, as pointed out by Humphreys [5] it is evident that uprushing currents of hurricane velocity must occur, e.g. in tornadoes, when

the many cases of lifting of heavy objects by the wind and their transport over considerable distances is considered. The conclusion to be drawn from this investigation seems, therefore, to be that the formation of the largest hailstones yet recorded can be explained on the assumption that growth proceeds from a stone of normal size by continued picking up of super-cooled water-drops while the stone is following a long trajectory relative to the air at a high level where temperature is well below the freezing-point, the speed of the uprushing current and the amount of condensed water required for the extreme cases being such as might reasonably be expected to be reached on occasions as rare as are those when stones of 8 cm. diameter or a little over are observed.

BIBLIOGRAPHY

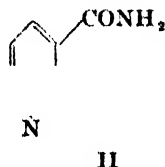
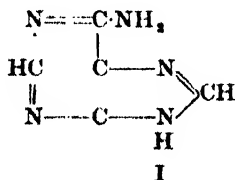
1. E. G. BILHAM and E. F. RELF, *Q.J. Met. Soc.*, **63**, 1937, 149.
2. A. WEGENER, *Vorlesungen über Physik der Atmosphäre*, Leipzig, 1935.
3. T. E. W. SCHUMANN, *Q.J. Met. Soc.*, **64**, 1938, 3.
4. W. TRABERT, *Met. Zeit.*, **16**, 1899, 433.
5. W. J. HUMPHREYS, *Month. Weath. Rev. Washington*, **56**, 1928, 314.
6. J. HANN and R. SÜRING, *Lehrbuch der Meteorologie*, Leipzig, 4 edn., 1926, 733.
7. W. H. McADAMS, *Heat Transmission*, McGraw Hill Book Co., 1933.

BIOCHEMISTRY. By W. O. KERMACK, D.Sc., LL.D., F.R.S.E., Research Laboratory, Royal College of Physicians, Edinburgh.

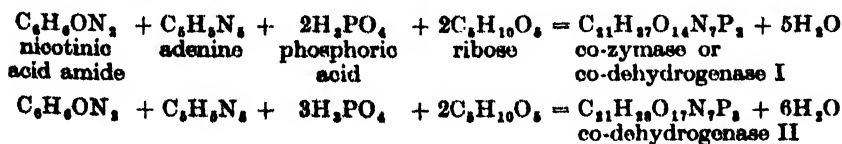
NICOTINIC ACID AND CO-ENZYMES.—The object of biochemistry is to give a description in terms of precise molecular structures, of the changes which take place within the living cell, and to relate these reactions to the functions and activities of the living tissues in which they occur. The physico-chemical system of even the simplest cell is, however, extremely complicated; at present the most fruitful line of approach seems to be that of concentrating attention on particular chemical reactions or systems of reactions, with the view of obtaining an exact and detailed picture of this limited field. In recent years a large amount of valuable work of this type has been carried out, especially in connection with the numerous processes of oxidation and reduction which proceed within the living cell. Most of this work, however, is too detailed and specialised to lend itself readily to summarising in these pages. For the most part it is concerned with the transfer of hydrogen from one compound to another, with the enzymes which promote these reactions, and with the specificity of those enzymes, that is to say, the determination of the range of compounds which a single enzyme will activate. Results in this field are, however, much more

interesting and significant when they refer not to isolated reactions but to whole systems of reactions, especially if the system is one which is probably of major importance in the normal metabolism of tissue. The description of muscle glycolysis in terms of the Emden-Meyerhof scheme of reactions, and the elucidation by Warburg and his school of the details of the oxidation—or rather the dehydrogenation—of hexose monophosphate by the enzyme system present in red blood cells, affords good examples of successful work of this type, and have already been discussed in these pages (SCIENCE PROGRESS, 1936, XXXI, 306).

Now an important component of the latter system is the compound called originally by Warburg the hydrogen-transporting co-enzyme. It was soon realised that this was closely related to the co-zymase of Harden and Young, the co-enzyme which is present in yeast juice and which is required for its fermenting activity. The further investigation by Euler of purified co-zymase has shown that by suitable fractionation, this may be separated into two very similar but distinct compounds. One of these is identical with the hydrogen-transporting co-enzyme, the other is the co-zymase proper. These are called by Euler co-dehydrogenase II and co-dehydrogenase I respectively. Both yield on hydrolysis adenine (I), phosphoric acid, nicotinic acid amide (II), and a reducing sugar, probably ribose, but whereas the hydrogen-transporting co-enzyme gives three molecules of phosphoric acid per molecule the co-enzyme gives only two.



According to the various analytical results, the following formulæ represent the formation of these two co-enzymes from their component parts :



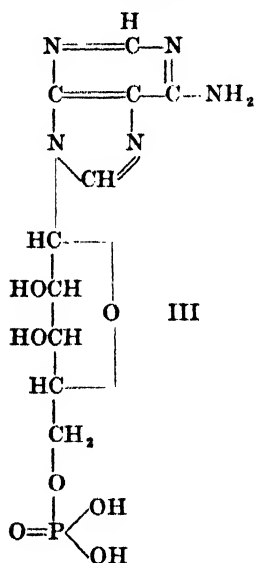
Because of their composition, Warburg calls these substances the diphosphopyridine-nucleotide and the triphosphopyridine-nucleotide respectively. The duplication of nomenclature is some-

what confusing and for convenience the following scheme is appended :

Diphosphopyridine nucleotide = co-dehydrogenase I = co-zymase
 Triphosphopyridine nucleotide = co-dehydrogenase II = hydrogen transport-
 ing co-enzyme of Warburg

Before discussing the more detailed structure of these two compounds, we may remark that in their biochemical behaviour they resemble each other even more closely than appeared originally to be the case. It was at first thought that co-dehydrogenase I promoted phosphorylation as well as dehydrogenation. Later work, however, seems to indicate that pure co-dehydrogenase I has no

phosphorylating action, and that the original observations were due to the fact that at the time the co-enzyme had not been obtained quite pure but contained adenylic acid (III) which would seem to be the unique phosphate-transporting co-enzyme.

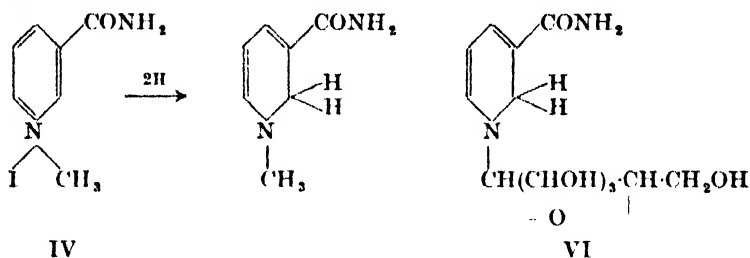


The three compounds adenylic acid, and co-dehydrogenase I and II are in fact found in close association, not only in yeast juice, but also in red blood cells, and apparently in most living tissues where glycolysis is going on. The two dehydrogenases both act as hydrogen acceptors, but it would seem for different substrates. Thus, whilst in the dehydrogenation of hexose monophosphate to the hexonic acid, it is co-dehydrogenase II which is active, in the dehydrogenation of alcohol to acetaldehyde it is co-dehydrogenase I which must be used. In both cases, the

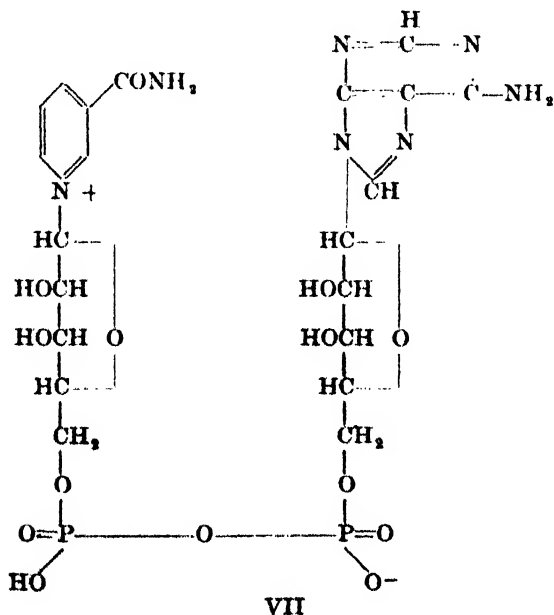
transport of hydrogen takes place only in the presence of a suitable protein enzyme, and it is of great interest to note that Negelein has actually obtained one of these *zwischen-ferments*, or intermediate enzymes, from yeast in a crystalline state (*Biochem. Z.*, 1937, **290**, 445).

In order to elucidate the structure of these somewhat complex substances, Karrer has prepared a series of model compounds. It was already clear that it was the nicotinic acid amide grouping which was the active centre and took up the hydrogen atoms. The dihydro derivative of the co-enzyme, which is readily formed either by biological reduction by means of the *zwischenferment*, as indicated above, or more simply by sodium hydrosulphite, differs

characteristically in its absorption spectrum from the oxidised form. Karrer has found that various simple quaternary salts of nicotinic acid amide, when acted upon by hydrosulphite, undergo reduction just as the co-dehydrogenase does (Karrer, Schwarzenbach, Benz, Solmssen, *Helv. Chim. Acta*, 1936, **19**, 811). Thus, for example, the methiodide of nicotinic acid amide (IV) is converted under these conditions to methyl dihydronicotinic acid (V).

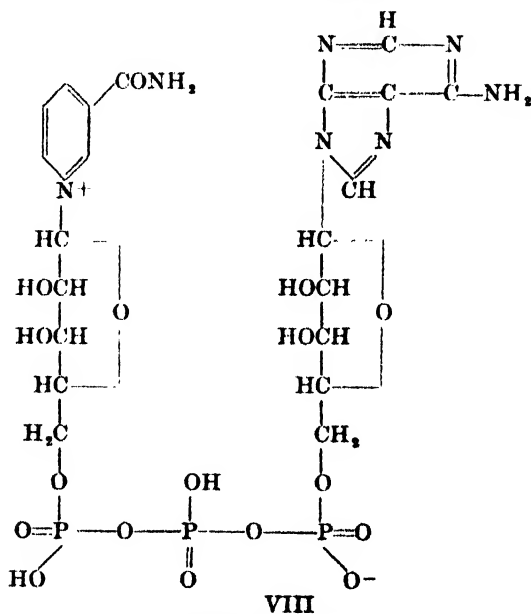


Of the many similar compounds which have been prepared and studied, the most interesting one is a glucose derivative (VI) prepared by acting on the base with tetra-acetylbromoglucose and after reduction to the dihydro derivative removing the acetyl groups from the product by heating with ammonia (Karrer, Ringier, Büchi, Fritsche, Solmssen, *Helv. Chim. Acta*, 1934, **20**, 55). It should be mentioned that the reduced sugar derivative is much more stable



VII
Co-dehydrogenase I

than the oxidised product. The co-dehydrogenases themselves, in the oxidised form, are likewise very easily decomposed with the liberation of free nicotinic acid, but relatively stable when reduced. Indeed, the general resemblance of this synthetic compound to the co-dehydrogenase molecule in many of its reactions is so great that there is little doubt that in the latter the nicotinic acid is united by a quaternary link to the ribose reducing group (*cf.* Karrer and Warburg, *Biochem. Z.*, 1936, **285**, 297). If now we bear in mind that in nature the co-dehydrogenases are always associated with an adenylic acid the following provisional formulæ, which do not appear to contradict any of the known facts, suggest themselves (*cf.* Euler und Schlenk, *Z. physiol. Chem.*, 1937, **246**, 64). Co-zymase, co-dehydrogenase I (VII), co-dehydrogenase II (VIII).



THE RÔLE OF CYTOCHROME IN CELL OXIDATION.—In the enzyme system studied by Warburg (*cf.* SCIENCE PROGRESS, 1936, XXXI, 306), the hydrogen atoms removed from the substrate, are first of all transferred in presence of a suitable protein *zwischenferment* to the co-dehydrogenase molecule and then to a lactoflavin nucleus, the second transfer also being promoted by a specific protein, namely the protein component of Warburg's yellow oxidation enzyme. The problem then naturally arises as to the relationship of this system to the cytochrome enzymes, which there is every reason to believe

play an important rôle in cell oxidation. It is characteristic of these latter substances, which contain iron as their active centre, that they are inactivated by cyanide, in contrast to the co-dehydrogenase lactoflavin system. Now it has been shown that the larger part of the whole oxidation going on in the living cell may be inhibited by cyanide. This at first sight seemed to indicate that most of the cell-oxidation went by way of cytochrome and that the flavine enzyme played only a minor rôle in the cell. But the latter is so widespread in nature that this latter conclusion appears inherently improbable. In a very interesting paper, Theorell has shed light on this problem (*Bioch. Z.*, 1936, 288, 317). He shows that, though the reduced form of the yellow pigment is rapidly oxidised by molecular oxygen at atmospheric pressure, the reaction proceeds only very slowly at the relatively low oxygen pressures such as exist in the normal living tissue. On the other hand, oxidised cytochrome brings about the oxidation much more rapidly than the free oxygen at those low pressures. Furthermore, the oxidised cytochrome does not act directly on, for example, the reduced form of co-dehydrogenase II, but only indirectly in presence of the yellow enzyme. All this seems to show that in the living cell, cytochrome is the natural oxidiser of the reduced form of the yellow pigment, that the systems co-dehydrogenase, yellow enzyme and cytochrome are in series and not in parallel. Just as co-dehydrogenase and yellow enzyme are hydrogen carriers, so cytochrome is an oxygen carrier, and the hydrogen on the yellow pigment unites with the oxygen on the cytochrome with the formation of water.

NICOTINIC ACID AND PELLAGRA.—It is clear from the above that nicotinic acid in the form of its amide is a very important constituent of the living cell. Experiments have demonstrated that it is essential for the growth of various micro-organisms (B. C. J. G. Knight, *Biochem. J.*, 1937, 31, 731). The question at once arises as to whether nicotinic acid or its amide is a necessary constituent of the diet of the higher animals. It will be remembered that in 1913, in the days when vitamin B (without suffix) denoted the antineuritic factor, and the existence of other related factors was not yet suspected, Funk (*J. Physiol.*, 1913, 46, 173) isolated from rice polishings a crystalline compound, which at first was thought to be the active substance. It was soon found, however, that what he had separated was nicotinic acid, presumably slightly contaminated by some highly active substance, and it was shown that pure nicotinic acid has no anti-neuritic effect. For the next couple of decades, little attention was paid to the possible importance of nicotinic acid in the animal organism, but great advances were made in our know-

ledge of vitamins. In particular vitamin B was found to be highly complex. It was first separated into an anti-neuritic factor, vitamin B₁, and a second "Pellagra Preventive" factor B₂. The work of Birch, György and Harris showed that the latter itself contained at least three components, the growth-promoting compound, lactoflavine, a factor B₃ which prevents the development of a dermatitis in rats, and a pellagra-preventing factor. At the same time dogs fed on a certain deficient diet were found to develop a condition known as "black tongue" (Birch, György and Harris, *Biochem. J.*, 1935, **29**, 2830), and it seemed very probable that the "black tongue" factor was identical with the pellagra preventive factor. In the circumstances, it was natural to investigate a possibility of nicotinic acid being one of these unknown factors. Experiments by Elvehjem in America (Elvehjem, Madden Strong, Wooley, *J. Am. Chem. Soc.*, 1937, **59**, 1767), and Harris at Cambridge showed that dogs suffering from "black tongue" were cured by the administration of pure nicotinic acid. As there was evidence that the canine "black tongue" factor and the human pellagra factor were identical, it seemed probable that nicotinic acid is the dietary constituent lacking in pellagra-producing diets. Harris (*Chem. and Ind.*, 1937, **56**, 1134) now reports that controlled trials made in Egypt on cases of human pellagra show that these are cured or much improved by administration of the acid. There would thus seem to be little doubt that a deficiency of nicotinic acid is a major factor in the production of pellagra. At the same time certain patients who developed the disease on a prison diet, did not recover completely, so that it is possible that frequently in pellagra other deficiencies may exist as well.

THE NATURE OF POTATO OXIDASE.—Most of the above work in the domain of enzyme chemistry is either the work of Warburg or owes its inspiration to him. The intense attack on problems in this field, which is at present being carried out in his institute, has resulted in the publication by Kubowitz of a paper which records an important advance (*Biochem. Z.*, 1937, **292**, 222). It is well known that potatoes, like many other vegetable tissues, contain an enzyme, which, in presence of atmospheric oxygen, oxidises catechol as well as several other polyphenols to the corresponding quinones. Kubowitz has worked out methods for the purification of this polyphenol oxidase, and though he has not succeeded in obtaining it crystalline, or even approximately free of impurities, he has been so far successful that he has obtained fairly conclusive evidence that the enzyme is a protein containing copper attached to it in a non-dialysable form. As in the case of the iron-containing

enzymes, the activity is inhibited by cyanide or carbon monoxide. This inhibition is presumably the result of the combination of the reagent with the heavy metal, preventing the change of the latter from the state of lower to that of higher oxidation. The enzyme would seem to act as a carrier of oxygen; the catechol is oxidised to the quinone by the cupric protein complex, the metal in the latter changing thereby into the cuprous state, and the reduced form of the enzyme is then readily reoxidised by atmospheric oxygen so that it is once more ready to act on the catechol.

The mode of action of the polyphenol oxydase is obviously rather similar to that of cytochrome described above. The latter, however, acts on the oxidised form of the yellow pigment in bringing about the reduction of the pyridine nucleotides. In other words, hexose monophosphate can be oxidised by the system *zwischenferment*, triphosphopyridine nucleotide, catechol, copper-containing oxidase, just as by the system *zwischenferment*, triphosphopyridine nucleotide, yellow pigment, cytochrome. Kubowitz has made use of this fact in order to overcome a difficulty which he encountered in making quantitative observations on the activity of his enzyme. The obvious plan would be to measure the rate of uptake of oxygen by catechol in solution in presence of the enzyme preparation. The difficulty arises that the product of the reaction, namely the quinone, poisons the enzyme so that the rate of the reaction rapidly falls off. Kubowitz therefore modifies the experiment so that he has present hexose monophosphate, *zwischenferment*, and triphosphopyridine nucleotide, and only a small quantity of catechol. The latter is thus kept almost entirely in the reduced state, and there is then never sufficient quinone present to interfere seriously with the activity of the enzyme. Readings of the oxygen uptake can be made over ten minutes, during which time the rate remains almost constant. Under the conditions chosen, this rate is proportional to the amount of enzyme present. Careful quantitative work shows that the activity of the highly purified solutions is proportional to the quantity of copper it contains, and this is the main evidence in support of the conclusion that copper is an integral part of the active molecule.

GEOLOGY. By G. W. TYRRELL, A.R.C.Sc., D.Sc., F.R.S.E., The University, Glasgow.

PETROGRAPHY OF IGNEOUS ROCKS—EXTRA-EUROPEAN.—In his memoir "Die Palæozoischen Eruptivgesteine von Canning Land" A. Noe-Nygaard (*Medd. om Grønland*, 118, Nr. 6, 1937, 153 pp.) gives a very full account of the geology and petrography of a plutonic

suite consisting of granite and granodiorite, and of a volcanic series consisting of hypabyssal porphyries and extrusive latites, andesites and dacites. These rocks are all of Devonian age. A valuable comparative section correlates these rocks with the very similar Devonian plutonic and extrusive rocks of Scotland, Scandinavia, Siberia and New Brunswick.

A paper by M. P. Fiveg on "The Apatite Deposits of the Khibinian Tundra" is the first of a symposium entitled "Geological Investigations of Agricultural Ores, U.S.S.R.," which was published for the 17th session of the International Geological Congress, 1937 (*Trans. Sci. Inst. Fertilisers and Insecto-fungicides, U.S.S.R.*, No. 142, 1937, 8-21). It deals especially with the petrology of the magmatic apatite-nepheline rocks which form the basis of phosphate mining in the Kola Peninsula. The apatite-rocks are closely related to a discontinuous annular intrusion of urtite and ijolite. The author thinks that the ore represents an injection of phosphatic residual melts into the already cooled and solidified ijolite.

V. Sobolev's memoir, "Petrologie der Trappen des Sibirischen Tafellandes" (*Trans. Arctic Inst. of the U.S.S.R.*, XLIII, 1936, pp. 1-214 Russian text, 215-24 German summary), is a valuable compilation of data on the least well known of the world's great "flood-basalt" regions. A central area of extrusive traps, which rest on the Tungus Series of Jurassic age, is surrounded by an extensive zone in which intrusive rocks, mainly sills, have been injected into the older rocks. The total area of lavas and intrusions is over a million sq. km. Petrographically the rocks are extremely uniform quartz-dolerites and over-saturated basalts, but differentiates ranging from ultrabasic to acid in composition occur in subordinate amounts. In a final chapter instructive comparisons of the Siberian Traps with the flood-basalt regions of Lake Superior, South America, South Africa, India, and the North Atlantic, are instituted, which serve to confirm the validity of the flood-basalt kindred with its highly distinctive geological and petrological characters.

On the basis of four new analyses of "plateau basalts" from Arctic Siberia, F. Loewinson-Lessing (*C.R. Acad. Sci. U.S.S.R.*, 1935, 53-6) concludes that these rocks compare chemically with the basalts of Greenland, Iceland and Franz Josef Land.

A paper on "The Alkaline Rocks of the Ishim River (West Siberia)," by A. N. Zavaritsky (*C.R. Acad. Sci. U.S.S.R.*, No. 7-8, 1936, 47-97 Russian text, 97-102 English summary), describes an area, 10 km. in diameter, consisting mainly of nepheline-syenite, but also with peculiar gneissoid cancrinite- and scapolite-syenites

along its margins. Essexite, kentallenite and monzonite occur in the eastern part of the area, and epi-leucite-porphyry has been found in the central part. Owing to poor exposures the geological relations of these rocks are practically unknown.

"Les laves des volcans des environs de Merghen, Mantchourie" are shown by A. N. Zavaritsky (*C.R. Acad. Sci. U.S.S.R.*, 1 (X), No. 9, 1936, 369-72) to be highly potassic rocks of intermediate composition allied to the gaussbergite of Antarctica and kajanite of Borneo. Lacroix has also remarked the alkaline and leucitic composition of Recent Manchurian lavas.

The fourteen "Recent Volcanoes of the Wu Ta Lien Chih district, Lung Chiang province, Manchuria" are described by T. Ogura *et alia* (*Survey Reports of Volcanoes in Manchuria*, No. 1, Ryojun Coll. of Eng., Manchuria, 1936, 1-84 Japanese text, 85-96 English summary). The lavas are highly potassic trachybasalts of which the most prevalent type, a basaltic glass with olivine, augite and occasionally leucite, is called *shihlunite*. The eruptions began with widespread olivine-basalts, followed by shield-cones of the same composition, and finally the historical cone eruptions of 1720.

The stratigraphical aspect of T. Tomita's memoir on the "Geology of Dôgo, Oki Islands, in the Japan Sea" (*Journ. Shanghai Sci. Inst.*, Sect. II, 11, 1936, 37-146) was dealt with in SCIENCE PROGRESS, XXXII, 1937, p. 112. But the work is mainly concerned with the petrography of the Tertiary igneous rocks. The eruptions began with a Pre-Miocene sequence of albitophyres, pyroxene-andesites, liparites, and again pyroxene-andesites, which were followed by a post-Miocene alkaline series of trachybasalts and basalts, trachyandesites, alkali-trachytes and alkali-liparites. The two suites, although occurring in the same restricted region, are perfectly distinct in regard to age, geological relations and petrographical characters.

Study of the radioactivity of the basalts of the Deccan Trap formation by V. S. Dubey and M. P. Bajpai (*Amer. Journ. Sci.*, XXXIV, 1937, 24-9) shows that the amounts of their radioactive contents have not varied much in the successive lava flows and younger dikes, and compare closely with that of the Acklington tholeiite of the north of England. Four new chemical analyses of Deccan basalts are given which appear to show that the western part of the Deccan Trap region is more alkalic than the central and eastern parts.

C. T. Barber's memoir on "The Tertiary Igneous Rocks of the Pakokku District and the Salingyi Township of the Lower Chindwin District, Burma, with Special Reference to the Determination of

the Felspars by the Federoff Method" (*Mem. Geol. Surv. India*, LXVIII, Pt. 2, 1936, pp. xii, 121-292) deals with a varied suite of igneous rocks that belong to an Eocene-Pliocene cycle of activity, which may be correlated with the rise of the Arakan Yoma geanticline, and the crumpling of the central part of the great Tertiary basin of Burma. The sequence is agglomerates, breccias and lavas mainly of andesitic composition, followed by intrusions of gabbro and diabase, and by a later volcanic phase which produced rhyolitic lavas and tuffs.

In an important paper on the "Igneous Geology of the Karang-kobar Region (Central Java), and its Significance for the Origin of the Malayan Potash Provinces," R. W. van Bemmelen (*De Ingenieur in Nederlandsch-Indie*, IV, *Mijnbouw en Geologie, De Mijn-ingenieur*, Jaarg. IV, No. 7, 1937, 115-35) deals with the petrology of the Neogene-Quaternary igneous rocks of the Karang-kobar and of the adjacent Diëng regions. In general these rocks belong to the calc-alkalic kindred, but there are also two intrusions of basic alkaline rocks. The origin of the calc-alkalic kindred and of the Malayan potassic provinces are discussed with the aid of 25 new analyses. The author arrives at the conclusion that the calc-alkalic (or tholeiitic) kindred may be derived from olivine-basalt magma by assimilation of sialic crustal material, and that the potassic rocks are "pathological" differentiates from calc-alkalic magmas due to the assimilation of limestone and subsequent loss of soda in the hydrothermal stage.

The first discovery of spilitic rocks in New Zealand is announced by J. A. Bartrum in two papers ("Spilitic Rocks in New Zealand," *Geol. Mag.*, LXXIII, 1936, 414-23; "Notes on the Geology of Three Kings and other Outlying Islands of Northern New Zealand," *N.Z. Journ. Sci. and Tech.*, XVIII, 1936, 520-30). The series consists of spilite, albite-porphry and quartz-keratophyre, and is described with the aid of three new analyses. The author comes to the conclusion that the albite and oligoclase of these rocks are primary in the fullest sense, and he dissents from the views of Gilluly and other writers that these minerals have been formed by metasomatic replacement.

In his paper on "Basic and Ultrabasic Rocks in North-west Otago," C. O. Hutton (*Trans. and Proc. Roy. Soc. N.Z.*, 66, 1936, 231-54) describes gabbroidal rocks, nephrites and tremolite-rocks, serpentinites and talc-schists, which have undergone mechanical and chemical changes under pressure for the origin of which the author invokes the aid of solutions derived from the basic magmas themselves.

P. Marshall describes the geology of Mayor Island (New Zealand), which is the upper part of a volcano composed of alkali-rhyolites, including comendite, obsidian and pantelleritic liparite, of which several new analyses are given (*Trans. and Proc. Roy. Soc. N.Z.*, 66, 1936, 337-45).

J. D. H. Wiseman gives petrographical descriptions and chemical analyses of four basaltic rocks dredged from the Carlsberg Ridge in the northern part of the Indian Ocean at a depth of 3385 m. (*Sci. Repts. John Murray Expedition, 1933-34*, 3, No. 1, 1937, 1-30). Three of the analysed rocks are oligoclase-basalts; the other is hornblende-augite-dolerite. They all show spilitic affinities, with low total iron, high soda and low potash. This is good evidence that the rocks represent submarine eruptions, and not a sunken land area. The rocks are chemically different from the Deccan Traps and the Gondwana basalts, and their content of radium (determined by J. H. L. Poole) is also systematically different.

It is impossible adequately to summarise A. Lacroix's great memoir on "Le Volcan Actif de L'Île de la Réunion et ses Produits" (Paris: Gauthier-Villars, 1936, pp. 297, 68 plates and map; *Lithology*, pp. 141-200) in a paragraph. It gives a description of the general geology and the petrology of the present volcano, the Piton de la Fournaise, and of the ancient volcanic massif called the Piton des Neiges. The lavas are mainly basalts and oceanites, but trachyandesites and trachytes also occur. Many new chemical analyses are published. The reader is referred to a review by R. A. Daly (*Amer. Journ. Sci.*, XXXIV, 1937, 405).

In their paper on "Helium-ratios of Rocks and Minerals from the Diamond Pipes of South Africa," A. Holmes and F. A. Paneth (*Proc. Roy. Soc. London*, A, 154, 1936, 383-413) show that the helium-ratio of kimberlite, corresponding to an age of 58 million years, is consistent with the Late-Cretaceous age assigned to the diamond pipes; and amphibolite xenoliths, known to be Pre-Cambrian, give "ages" much higher than kimberlite. Three eclogite nodules also have high helium-ratios, and are thus proved to be accidental xenoliths derived from pre-existing country-rocks, and not early segregations from kimberlite magma as formerly thought.

A. Holmes has made an outstanding "Contribution to the Petrology of Kimberlite and its Inclusions" (*Trans. Geol. Soc. S. Africa*, XXXIX, 1936, 379-427), with the aid of 12 new analyses by L. S. Theobald. As a result it is stated that kimberlite magma can now be regarded as the chemical equivalent of olivine-melilitite (formerly melilitite-basalt) to which abundant water and carbon dioxide, with some CaO, P_2O_5 , and other minor constituents, have

been added. The inclusions of the peridotite suite are believed to represent an ultrabasic layer occupying a deeper level than that from which the eclogites were derived.

In a valuable memoir on "The Magmatic Nickeliferous Ore Deposits of East Griqualand and Pondoland," D. L. Scholtz (*Trans. Geol. Soc. S. Africa*, XXXIX, 1936, 81-210) discusses the geology, petrology and ore deposits of the great gabbro-norite massifs of Insizwa, Tonti, Tabankulu and Ingeli. Apparently he regards these masses as erosion remnants of an originally single intrusive sheet which was characterised by roughly parallel but markedly undulatory upper and lower surfaces. Three petrographical units are distinguished: (1) roof zone with rocks of granitic composition; (2) central zone, consisting primarily of gabbro; (3) basal zone, characterised by picrites or olivine-rich hyperites, which is the repository of the ores. The petrography of the intrusion is discussed with the aid of numerous new analyses. All available evidence seems to indicate that the ore behaved in a manner essentially analogous to a residual granitic magma, and retained its liquid condition after the majority of the silicates had crystallised.

The lavas of Bufumbira (see later paragraph) and the melilite-rich lava of Katunga in south-west Uganda contain an abundance of transfused quartz xenoliths, which are partly altered to a glass having much the same composition as a potash-rich acid obsidian. These inclusions have been investigated by A. Holmes (*Min. Mag.*, XXIV, 1936, 408-21) with the aid of the micro-chemical technique developed by F. Hecht, who carried out the analyses himself. The formation of alkali-rich glass is ascribed to the transfusion of emanations from the basic and ultrabasic alkalic lavas in which the quartz xenoliths are enclosed.

The Katunga volcano of south-west Uganda and the petrography of its lavas are described by A. D. Combe and A. Holmes respectively (*Geol. Mag.*, LXXIV, 1937, 195-219). The new rock type *katungite* is defined as an alkalic ultrabasic rock with more potash than soda, consisting of essential melilite and olivine. Discussion of the origin of *katungite* and related lavas follows the same lines as in Holmes's larger memoir on Bufumbira (see next paragraph).

The Tertiary and Recent volcanic rocks of the Bufumbira area in south-west Uganda are described in great detail in a magnificent memoir by A. Holmes (petrology) and H. F. Harwood (chemical analyses) (*Geol. Surv. Uganda*, Mem. No. III, Part II, 1937, pp. xiv+300). The rocks are classified in six main groups: olivine-leucite series; melilite-feldspathoid series; leucite-basanite series; potash-trachybasalt series (absarokite-shoshonite-banakite series);

potash-trachyandesite or latite series ; and limburgite-trachybasalt series. Many of these lavas contain ejected blocks and inclusions of plutonic habit such as peridotite and biotite-pyroxenite. A valuable final chapter on petrogenesis based on these observations elaborates the theory of metasomatism and transfusion by magmatic emanations which Holmes and D. L. Reynolds have urged in recent years. Twenty-six new analyses are contributed to the discussion, and several apparently justifiable new rock names have been coined.

"The Chilwa Series of Southern Nyasaland ; a Group of Alkaline and Other Intrusive and Extrusive Rocks and Associated Limestones," by F. Dixey, W. Campbell Smith and C. B. Bisset (*Nyasaland Protectorate : Geol. Surv. Dept. Bull.*, No. 5, 1937, 85 pp.), is another important memoir on African petrology, dealing with a group of alkaline igneous rocks regarded as marking a hitherto unrecognised phase of Karroo or early post-Karroo igneous activity. The Chilwa Series comprises a group of vents of pipe-like form, infilled mainly by limestone which is thought to be of deep-seated origin, and with a minor development of hydrothermal rocks. Some of these vents are invaded by intrusions of syenite and nepheline-syenite, and one by ijolite, which are cut, in their turn, by a varied suite of dike-rocks including phonolite, camptonite and olivine-nephelinite. Feldspathic intrusions and breccias in the vents, felsitic or rhyolitic in appearance, turn out to consist of a rare rock type containing 70 per cent. or more of orthoclase. The main features of the Chilwa vents are similar to those of the classic Fen district of Norway ; and here, as there, the problem of the origin of the alkaline rocks is closely related to that of the associated limestones.

S. J. Shand's observations on "The Rocks of the Kedong Scarp, Kenya Rift Valley" (*Geol. Mag.*, LXXIV, 1937, 262-71) cover four rock-groups : (a) trachyte lavas and tuffs, forming nine-tenths of the cliff ; (b) porphyritic olivine-basalt forming the base of the scarp ; (c) syenite-porphyry occurring on the rim of the Kijabe terrace ; and (d) enclosures of obsidian and augitite in the Kijabe tuff. The mineralogical and chemical relationships between the basalt and the augitite suggest that both rocks may have been derived from the same magma by the flotation of early plagioclase crystals with concurrent subsidence of early crystals of augite and hornblende.

A. M. Champion describes the recent and active volcanoes of the region around the southern end of Lake Rudolf, Kenya Colony (*Zeitschr. f. Vulk.*, XVII, 1937, 163-72), with petrographical notes by W. Campbell Smith. The latter author mentions basanitoid,

phonolitic, trachyte, phonolite, and nepheline-basanite, as products of these volcanoes.

The field-relations of "The Late Tertiary Igneous Rocks of Egypt" are described by G. Andrew (*The Egyptian Univ. : Bull. Fac. Sci.*, No. 10, 1937, 61 pp.). The rocks consist of olivine-basalts and olivine-dolerites, some of which show alkaline affinities in the common presence of interstitial primary analcite. An alkaline character is pronounced in the rocks of the vents of south-western Egypt and of the Wady Araba in eastern Egypt. The Egyptian Tertiary petrographical province appears to form a part of that of Equatorial Africa, and may be related to the younger igneous rocks of Abyssinia and Arabia.

The Late Tertiary and recent volcanic rocks of Nicaragua, described by C. Burri and R. A. Sonder (*Zeitschr. f. Vulk.*, XVII, 1936, 34-92), consist of olivine-basalts, augite- and hypersthene-andesites, dacites and rhyolites. They are closely related to the lavas of Lassen Peak and the Sierra Nevada. Many new analyses are recorded.

In a memoir on the "Ring-dike Complex of the Belknap Mountains, New Hampshire," D. Modell (*Bull. Geol. Soc. Amer.*, 47, 1936, 1885-1932) writes: "The geological map of the Belknap Mountains shows an igneous complex marked by a notable annular arrangement of its units. The Albany quartz-syenite forms an arcuate, almost oval-shaped, intrusive ribbon. Symmetrically grouped along the western edge of the complex are arcuate masses of quartz-syenite, syenite, and monzodiorite. . . . In the south-eastern part of the Belknap complex, two arcuate remnants of the schists and intrusives older than the White Mountain Magma Series further accentuate the structure. This dominance of annular arrangement is too marked to be the result of chance distribution of intruding magmas. From the petrological distribution pattern alone, the conclusion must be drawn that a specialised tectonic mechanism—that of ring-intrusions—has been operative."

The alkaline rocks at Red Hill, New Hampshire, described by A. Quinn (*Bull. Geol. Soc. Amer.*, 48, 1937, 373-402) probably form a ring-structure with an outer ring of coarse syenite, an inner ring of nepheline-sodalite-syenite, and a central mass of syenite (the Firetower Syenite). The last-named is cut by three small plugs of quartz-syenite, syenite and fine-grained granite. On the other hand, the author thinks that the mass may possibly represent a plug of coarse syenite partly eviscerated by later intrusions. The rocks belong to the White Mountain Magma Series, and the intrusion is one of a series which commonly take the form of ring dikes.

In his paper on "Petrology of the Syenite Stock at Cherry Mountain, New Hampshire," R. W. Chapman (*Amer. Journ. Sci.*, XXXIII, 1937, 161-86) shows that this mass constitutes an elliptical stock intrusive into older granites. It covers an area of $3\frac{1}{2}$ sq. miles, and is built of syenites belonging to the White Mountain Magma Series. It is believed to have been emplaced by cauldron subsidence in post-Lower Devonian times.

The "Geology of the Cardigan Quadrangle, New Hampshire," is described by K. Fowler-Lunn and L. Kingsley (*Bull. Geol. Soc. Amer.*, 48, 1937, 1363-86). The rocks consist of a basement of Littleton Schists (Devonian) which is injected by a series of intrusions belonging to the New Hampshire Magma Series. The latter consist of the Bethlehem Gneiss, Kinsman Quartz-monzonite and Concord Granite, which are all sill-like bodies. The injections took place while pressures were still operating, with the result that gneissic structures have been produced.

The Lincoln Sill, Maine, described by J. M. Trefethen (*Journ. Geol.*, XLV, 1937, 353-80), varies from a porphyritic alkali-syenite, through syenite and monzonite, to augite-diorite near the contacts. The attitude of the sill is nearly vertical, in accordance with the attitude of the country rocks. It is thought possible that hybridism accounts for the unusual composition of the rocks.

In his "Review of the Problems of the Sudbury Irruptive," T. C. Phemister (*Journ. Geol.*, XLV, 1937, 1-47) approaches the subject from two points of view: (1) the nature of the intermediate zone between the acid and basic portions; (2) the place of the assemblage within the Keweenawan petrographical province. He considers that the intermediate rocks are hybrid types formed at the contact between solidified basic rocks and acid magma. The basic member probably represents the products of fractionation of the parent diabase magma of the province, and also an early separating olivine-diabase component.

In G. R. Heyl's memoir "Geology and Mineral Deposits of the Bay of Exploits Area" (*Newfoundland Dept. of Nat. Resources, Geol. Sect. Bull.*, No. 3, 1936, 66 pp.) is an account of a great volcanic episode in Ordovician times which produced a typical spilitic series, accompanied by dolerite dikes and a laccolith of dolerite; and later, by intrusions of diorite and gabbro. An orogenic deformation followed, probably at the end of the Silurian, which was marked by the intrusion of batholiths of granodiorite with lamprophyre dikes. The petrography of these rocks is illustrated by several new analyses.

The memoir by J. R. Cooper on the "Geology of the Southern

Half of the Bay of Islands Igneous Complex " (*Newfoundland Dept. of Nat. Resources, Geol. Sect. Bull.*, No. 4, 1936, 62 pp.) is primarily a petrological and structural study of a part of the western serpentine belt of Newfoundland. This belt consists of four large masses of serpentine, with accompanying basic and ultrabasic rocks which show marked gravity-stratification. These four masses are interpreted as erosion remnants of a single lopolithic or sheet-like intrusion. The petrography of this remarkable massif is illustrated by seven new analyses.

The above-cited memoir dealt mainly with the two southernmost ultrabasic masses of the Bay of Islands complex. A. F. Buddington and H. H. Hess, in a paper on "Layered Peridotite Laccoliths in the Trout River Area, Newfoundland" (*Amer. Journ. Sci.*, XXXIII, 1937, 380-8), suggest that the type of structure postulated by Cooper may be applied to the two northern masses, and criticise adversely E. Ingerson's view that they represent tilted laccoliths (*Amer. Journ. Sci.*, XXIX, 1935, 422-49). Ingerson briefly replies reasserting his hypothesis (*Amer. Journ. Sci.*, XXXIII, 1937, 389-92).

T. L. Kesler has come to the following conclusions in his study of the "Granitic Injection Processes in the Columbia Quadrangle, South Carolina" (*Journ. Geol.*, XLIV, 1936, 32-44). The intrusion of granite and the conversion of volcanic and sedimentary rocks into schist are results of the same geological cycle. Schist near the granite has been subjected to *lit-par-lit* injection and replacement by granitic material. An advanced stage of injection and replacement is expressed by granitic rock in which schistose and gneissose structures are preserved; but in an extreme stage, inherited structures have been obliterated, the resulting rock being a contaminated granite.

The Stillwater banded complex of basic and ultrabasic rocks, exposed in the Beartooth Mountains of Montana, is the subject of two papers, one by J. W. Peoples (*Rept. XVth Internat. Geol. Congr.*, Washington, 1933, 1936, 353-60), and the other by A. L. Howland, J. W. Peoples and E. Sampson (*Montana Bureau of Mines and Geology, Miscell. Contribns.*, No. 7, 1936, 1-15). It consists of a basal norite, interpreted as a chilled facies, followed by 2500 feet of pyroxenite and peridotite, and finally by a banded norite—anorthosite facies. The mass is regarded as a sheet or lopolith tilted up on edge and locally overturned. The arrangement of the several layers is interpreted as gravity stratification. The second paper deals with the complex mainly as a source of nickel, chromium and platinum.

L. V. Pirsson's early study of the famous Shonkin Sag laccolith

of Montana led to its being regarded as a classic example of differentiation in place within a single intrusion. On the basis of new and much more detailed field and laboratory data than Pirsson's, J. D. Barksdale (*Amer. Journ. Sci.*, XXXIII, 1937, 321-59) holds that the well-marked layering of the laccolith is best accounted for by the hypothesis of three separate intrusions.

"The Volcanic Rocks of the Valley Area, Park County, Wyoming," are described by J. T. Rouse (*Trans. Amer. Geophys. Union, 16th Ann. Meeting*, 1935, 274-84). They consist of basic tuffs and breccias, with a thick intercalation of basaltic lavas which include, beside ordinary basaltic types, the highly potassic basic lavas known as leucite-absarokite. Some of the breccias represent volcanic mud-flows.

The "Igneous Geology of the Spanish Peaks Region, Colorado," previously well known because of its radial dike-swarm, is exhaustively dealt with by A. Knopf (*Bull. Geol. Soc. Amer.*, 47, 1936, 1727-84). Two stocks, respectively consisting of granite and granodiorite-porphyry, and of syenite, underlie the peaks. The dikes, more than 500 in number, radiate from these masses, and consist of minettes, vogesites, camptonites, fourchites and teschenites. Because of the abundance of analcite, indicating high water content, some of the dikes are of plutonic habit.

"Scores of volcanic necks, dikes and lava-capped mesas rise from the high plateau of north-east Arizona and the adjacent parts of Utah and New Mexico." Howell Williams describes the geology and petrology of these "Pliocene Volcanoes of the Navajo-Hopi Country" (*Bull. Geol. Soc. Amer.*, 47, 1936, 111-72). The Hopi Buttes volcanic field consists of limburgites, analcite-basalts and monchiquites, trachybasalts and olivine-basalts; the Navajo fields include a well-marked cauldron-subsidence, and the lavas are sanidine-trachybasalts corresponding to the potash-rich intrusive rocks which form minettes, leucitites, monchiquites and alnöites. All these masses contain an abundance of foreign inclusions consisting of acid plutonic and gneissic rocks, schists, norites and lherzolites. The magma-types are of alkaline characters, and there is a regional variation from a slightly sodic type in the south to a strongly potassic type in the north.

C. A. Anderson describes the "Volcanic History of the Clear Lake Area, California" (*Bull. Geol. Soc. Amer.*, 47, 1936, 629-64). The volcanicity began with a flow of olivine-basalt with tuffs and breccias of Late Pliocene or Early Pleistocene age. Mt. Konocti is an eroded multiple composite cone built chiefly of rhyodacite lavas and tuffs. Recent volcanic activity is represented by the explosion-

crater of Little Borax Lake, the hypersthene-dacite plug-dome of Chalk Mt., cinder cones and various lava flows. Quicksilver deposits are associated with the recent eruptives of Sulphur Banks.

The "Petrology of the San Marcos Gabbro, Southern California," is described in detail by F. S. Miller (*Bull. Geol. Soc. Amer.*, **48**, 1937, 1397-1426). The main rock types are norite and hypersthene-gabbro, with large areas of hornblende-gabbro. Olivine-norite and eucrite also occur. These gabbros, of which 40 bodies are known in an area of 60 sq. miles, represent the initial phase of a Jurassic composite batholith which consists mainly of tonalite and granodiorite. All of the San Marcos gabbro types were derived ultimately from the same parent magma, and form a continuous fractional differentiation series from norite, through quartz-biotite-norite and quartz-biotite-hornblende-gabbro, to tonalite. The irregular distribution of hornblende reflects an original erratic distribution of mineralisers in the intrusion.

J. Verhoogen has published an interesting study of "Mount St. Helens: A Recent Cascade Volcano" (*Univ. of Cal. Publ., Bull. Dept. Geol. Sci.*, **24**, No. 9, 1937, 263-302). The rocks consist mainly of basalts, andesites, dacites and pyroclastics of various types. The volcano rests on a platform consisting of Eocene (?) sediments and Kechulus Andesite lavas (Miocene). It was built up at the close of the Glacial epoch and, beginning with the outpouring of olivine-basalts, continued with successive eruptions of basalts and andesites. The pyroclastics are restricted mostly to the very early and late stages of activity. Plugs or domes of andesite and dacite occur at the summit of the volcano and at several points on its flanks.

Numerous dikes and plugs, and a few small stocks, ranging petrographically from augite-diorite to granite, penetrate the Tertiary volcanic rocks in a narrow belt extending longitudinally through the Cascade Range of Oregon. These rocks, and their somewhat extensive contact-zones, are fully described by A. F. Buddington and E. Callaghan (*Amer. Journ. Sci.*, **31**, 1936, 421-49). The replacement of plagioclase by orthoclase is a common feature in these intrusive bodies.

INVERTEBRATE PALEONTOLOGY. By H. DIGHTON THOMAS, M.A., Ph.D., F.G.S., British Museum (Natural History).

THE remarkable Middle "Cambrian *Centropleura vermontensis* Fauna of Northwestern Vermont" (B. F. Howell, *Bull. Geol. Soc. Amer.*, XLVIII, 1937, 1147-1210) includes the earliest chordate so far discovered. The most nearly related fauna is the slightly

older one of Bennett Island, off northern Siberia, while the *Paradoxides forchammeri* fauna of Scandinavia is also allied.

An enormous work in four volumes entitled "Études géologiques sur le Maroc central et le moyen Atlas septentrional," by H. Termier (*Notes Mém. Serv. Mines Carte Géol. Maroc*, XXXIII, 1936, 1-1566), gives a full description of the stratigraphy, structure, palæontology and petrology of the region.

The "Eocene Beds of the Punjab Salt Range" have been investigated by L. M. Davies and E. S. Pinfold (*Paleont. Indica*, n.s., XXIV, 1, 1937, 1-79). The Ranikot Beds are overlain unconformably by the Laki, with a notable change in fauna. The fossils described are mainly the larger foraminifera. The fauna shows that a close correlation can be made between the Ranikot beds of the area considered and those of Tibet.

In "Palæontologia della Somalia," A. Silvestri monographs the foraminifera (*Paleont. Ital.*, XXXII, suppl. 2, 1937, 45-264) and R. Zuffardi-Comerci (*ibid.*, 265-301) the corals from the Oligocene and Miocene beds. Both authors show the stratigraphical distribution of the various species.

The "Fusulinids of the Subfamily Schubertellinæ" have been studied by M. L. Thompson (*Journ. Paleont.*, XI, 1937, 118-25), who shows that the genotype of *Schubertella* is Permian in age, and that it possesses a spirotheca composed of a tectum, and a rather thick inner layer of light material. Further, L. G. Henbest (*ibid.*, 212-30) has proved that a typical keriothecal wall-structure is present in several well-known American species of *Fusulina*, as had been maintained by J. J. Galloway. This necessitates a re-definition of the Family Fusulinidæ and of its two sub-families, the Fusulininæ and the Schwagerininæ.

Other important papers on the distribution and structure of the Fusulinidæ are by the following: C. O. Dunbar and J. W. Skinner (*Bull. Univ. Texas*, 3701, 1937, 517-825), J. S. Lee (*Bull. Geol. Soc. China*, XVI, 1937, 58-99), F. and G. Kahler (*Paleontographica*, LXXXVII, A, 1937, 1-44 and *Compt. Rend. Deux. Congr. Avanc. Etudes Strat. Carb. 1935*, 1937, 445-87), M. L. Thompson and C. L. Foster (*Journ. Paleont.*, XI, 1937, 126-44), H. Huzimoto (*Jap. Journ. Geol. Geog.*, XIV, 1937, 117-25), N. D. Newell and R. P. Keroher (*Journ. Paleont.*, XI, 1937, 698-705), and D. Rauser-Cernousova (*Publ. Labor. Paleont. Moscow Univ. Stud. Micropaleont.*, I, 1, 1937, 9-26).

"Studies of Mexican Fossil Foraminifera" enable R. W. Barker and T. F. Grimsdale to demonstrate the presence of an interseptal canal-system in the three sub-genera into which *Miogypsina* is

divided. They also believe that a similar system exists in *Rotalia*, from which genus they postulate that *Miogypsinoides* was evolved directly in the Middle Oligocene (*Ann. Mag. Nat. Hist.*, ser. 10, XIX, 1937, 161-78).

In discussing the morphology of the foraminifer *Spiroclypeus* and reviewing its known species, Tan Sin Hok (*De Ingenieur in Nederlandsch-Indie*, IV, 1937, 177-93) concludes that that genus and *Cycloclypeus* have originated along two separate lines from *Heterostegina*.

In "Planktonforaminiferen aus der Kreide und dem Eozän und ihre stratigraphische Bedeutung" (*Publ. Labor. Paleont. Moscow Univ. Stud. Micropaleont.*, I, 1, 1937, 27-46), M. F. Glaessner recognises fifteen horizons distinguished by their foraminiferal assemblages, and suggests that the species of *Globotruncana* are of stratigraphical significance.

Z. Sujkowski discusses "Les radiolarites du gothlandien inférieur des Monts de Ste. Croix en Pologne" (*Bull. Serv. Géol. Pologne*, IX, (1), 1937, 69-88), and considers that the vast extent of the Gothlandian deposits, their association with volcanic submarine eruptions, and their limitation to geosynclinal areas point to their being oceanic deposits. They are an extreme facies of the graptolitic shales, which he concludes were not deposited in enclosed gas-poisoned seas, but under conditions approximating to those of the Sargasso Sea, though differing from them in the lack of aeration of the bottom waters.

T. H. Ting has carried out a "Revision der Archæocyathinen," in which group he recognises the presence of spicules and of four types of canal-system (*Neues Jahrb. Min., etc.*, LXXVIII, B, 1937, 327-79). He concludes that those organisms are to be classed in the sub-order Tetracladina of the Porifera. A. G. Vologdin also considers that they belong to that phylum, and divides them into two classes, Regular and Irregular (*Publ. Labor. Paleont. Moscow Univ. U.S.S.R. Probl. Paleont.*, II-III, 1937, 453-500).

Acanthograptus suecicus (Wiman) (O. M. B. Bulman, *Geol. Fören. Förhandl.*, LIX, 1937, 182-8) possesses a peculiar grouping of the elongate, tubular thecæ into twigs. This feature may have been attained along more than one line of descent leading to various genera.

G. L. Elles discusses "The Classification of the Ordovician Rocks" (*Geol. Mag.*, LXXIV, 1937, 481-95), and maintains that the zone of *Nemagraptus gracilis* falls within the Llandeilian, for the elements of its graptolitic fauna are those of the Leptograptid fauna.

"Die Graptolithen fauna im unteren Didymograptusschiefer

(Phyllograptusschiefer) Norwegens," by A. Monsen (*Norsk geol. tidsskr.*, XVI, 1937, 57-266), is an important monograph of the graptolites of the Lower Ordovician of Norway, of which 122 species and varieties are described.

"*Conchopeltis* Walcott, an Ordovician genus of the Conulariida," is shown by J. B. Knight to have had a quadrilateral radial symmetry, and four symmetrically arranged pairs of markings resembling muscle-scars. He therefore suggests that *Conchopeltis*, the Conulariida, and the Tentaculitida would be better classed either with the Hydrozoa or the Scyphozoa than with the Mollusca (*Journ. Paleont.*, XI, 1937, 186-8).

The tabulate corals from the Devonian limestones of the eastern slopes of the Urals, discussed by V. Porfiriev (*Mater. Centr. Geol. Prosp. Inst. U.S.S.R. Paleont. Strat.*, III, 1937, 22-34), belong mostly to the genus *Favosites*. In addition, "The Australian Massive Species of the Coral Genus *Favosites*" have been monographed by O. A. Jones (*Rec. Austral. Mus.*, XX, 1937, 79-102). This author is able to recognise two general tendencies, namely, (1) the Middle Devonian forms have thicker walls than those of the Silurian, and (2) incomplete tabulae are more common in the former than in the latter.

"Individual Variation in the Rugose Species *Heliophyllum halli* E. and H." is an important study by J. W. Wells (*Paleont. Amer.*, II, 6, 1937, 1-22). On the basis of a large number of specimens, he shows that the six species and two varieties of *Heliophyllum* previously recorded from the Middle Devonian Ludlowville Formation of New York really fall into one species and one variety.

E. C. Stumm's study of "The Lower Middle Devonian Tetracorals of the Nevada Limestone" (*Journ. Paleont.*, XI, 1937, 423-43) shows that they find their closest analogues in the Calceola Limestone of the Rhine Valley, and not in the Onondaga Limestone of North America.

In their stratigraphical distribution the "Corals of the Upper Silurian and Lower Devonian of the Eastern and Western Slopes of the Urals" are shown by E. Soshkina to compare well with those of North America and Europe, especially with those of the Silurian of Gotland (*Trav. Inst. Paléozool. Acad. Sci. U.R.S.S.*, VI (4), 1937).

The simple corals of the Middle Carboniferous of the Moscow Basin are dealt with by T. Dobrolyubova (*ibid.*, (3), 1937, 1-92), and by N. Kabakovitch (*ibid.*, (3), 1937, 93-116). The two higher horizons, which yield the richer coral fauna, can be identified by their characteristic species of *Bothrophyllum*.

"Les Échinides fossiles du Sénégal," described by J. Lambert

and F. Jacquet (*Bull. Soc. Géol. France*, 5 sér., VI, 1936 (1937), 339-61), come from the Upper Cretaceous and Eocene. Other African echinoids are monographed by J. Lambert in "Échinides fossiles du Maroc" (*Notes Mém. Serv. Mines Carte Géol. Maroc*, XXXIX, 1937, 1-109). Jurassic, Cretaceous, and Tertiary species occur. This paper also includes a review of the stratigraphy by H. Termier.

"Neue Beiträge zur Kenntnis der permischen Echinodermen von Timor VIII-XIII," by J. Wanner (*Palæontographica*, Suppl.-Bd. IV, IV Abt., 2 Lief., 1937, 57-212), is a monograph of some of the families of the beautifully preserved Permian crinoids of Timor. Many new genera and species are described.

K. St. Joseph has determined the internal structures of *Camarotoechia borealis* (von Buch 1834, ex Schlotheim 1832) and of *Rhynchotreta cuneata* (Dalman) by grinding down specimens from the umbones to give serial drawings or transfers, from which enlarged scale models were prepared (*Geol. Mag.*, LXXIV, 1937, 33-48 and 161-76).

B. Licharew discusses the Chonetidæ and the Productidæ in "Brachiopoda of the Permian system of U.S.S.R." (*Paleont. U.S.S.R. Monog.*, XXXIX, 1, 1937, 1-151). He holds that the various genera into which *Productus* has been divided are to be considered as only sub-genera, and stresses the importance of the trail and of the marginal characters in classification.

In "Die deutschen Zechsteinbrachiopoden" (*Abhandl. Preuss. Geol. Landesanst.*, N.F., CLXXXV, 1937, 1-77) E. Malzahn gives full descriptions of the several species, and discusses the variations to be found in *Productus horridus* and its varieties and in *P. timanicus*, as well as their descent.

The "Stratigraphic Significance of Some Late Paleozoic Fenestrate Bryozoans" in Kansas is demonstrated by M. K. Elias (*Journ. Paleont.*, XI, 1937, 306-34). The fenestrellids show evolutionary changes in the increase of distance between branches, dissepiments, zoecia, and spines. Interesting morphological and stratigraphical results are also deduced by A. H. McNair in his studies on "Cryptostomatous Bryozoa from the Middle Devonian Traverse Group of Michigan" (*Contrib. Mus. Paleont. Univ. Michigan*, V, 9, 1937, 103-70). A correlation of that series with the New York Hamiltonian is indicated.

Those interested in Carboniferous stratigraphy, faunas, and floras, will find numerous important papers in *Compt. Rend. Deux. Congr. Avanc. Etudes Strat. Carb. 1935*, 1937. "The Coal Measures of Bristol and Somerset," by L. R. Moore and A. E. Trueman (*Quart.*

Journ. Geol. Soc. Lond., XCIII, 1937, 195-240), should also be consulted. In addition, the non-marine shells of the Carboniferous are the subject of works by A. Wood (*Quart. Journ. Geol. Soc. Lond.*, XCIII, 1937, 1-22), D. Leitch (*Trans. Geol. Soc. Glasgow*, XIX, 1937, 390-408), and B. J. Tschernyschew (*Mater. Centr. Geol. Prosp. Inst. U.S.S.R. Paleont. Strat.*, III, 1937, 17-21).

The discovery of Lower Triassic marine fossils in the Chinglung Limestone of the Lower Yangtze Valley and the Nanking Hills is of importance, as few diagnostic fossils have been previously found or described from those areas. Indeed, marine Triassic rocks are far from widely developed in China. The new discoveries are discussed by T.-Y. Hsu in "Contributions to the Marine Lower Triassic Fauna of Southern China" (*Bull. Geol. Soc. China*, XVI, 1937, 303-346). They include lamellibranchs and ammonites.

V. Pcelincev shows that the molluscan faunas of the Liassic and Lower Dogger deposits of the Crimea and the Caucasus belong to the Middle European province. He also gives a useful account of the stratigraphy of those regions (*Paleont. U.S.S.R. Monog.*, XLVIII, 1, 1937, 1-86).

An extraordinary discovery is the occurrence of freshwater lamellibranchs with a hinge-structure reminiscent of *Trigonia* in Senonian deposits in Indo-China (J. H. Hoffet, *Bull. Serv. Géol. Indochine*, XXIV, 1, 1937, 1-25).

In his study of the geology of the Province of Camaguey, Cuba, H. J. MacGillivray has carried out a revision of the rudistids (*Geog. Geol. Meded. Min. Geol. Inst. Rijks-Univ. Utrecht, Physiogr.-Geol. Reeks*, XIV, 1937, 1-168).

"The Wangaloan and Associated Molluscan Faunas of Kaitan-gata—Green Island Subdivision" are considered by H. J. Finlay and J. Marwick to be of Danian age. These New Zealand molluscs would seem to show that the period between the Mæstrichtian and the Palæocene was much longer than is generally conceded. The fauna includes several new genera and species (*New Zealand Geol. Surv. Palæont. Bull.*, XV, 1937, 1-140).

Important monographs of American mollusca are those on the Oligocene and Lower Miocene shells of Florida by W. C. Mansfield (*State Florida Dept. Conserv. Geol. Bull.*, XV, 1937, 1-334), and on the Tertiary Texan gastropods, mainly of Eocene age, by G. D. Harris (*Palæont. Amer.*, II, 7, 1937, 1-122).

Shantungendoceras, a new genus of the nautiloidea from China, is the first true Holochocanite from Cambrian rocks. Y. C. Sun considers that later forms are derived from it (*Bull. Geol. Soc. China*, XVI, 1937, 347-56). He holds that *Volborthella* is a primitive

cephalopod, possibly ancestral to the new genus. As a result of investigations on "*Salterella conulata* and its Allies," T. Kobayashi concludes, however, that certain species of *Salterella*, together with *Volborthella tenuis*, form a group of mollusca intermediate between the Hyolithidæ and the Nautiloidea (*Jap. Journ. Geol. Geog.*, XIV, 1937, 173-83).

Of outstanding importance is the critical survey by F. B. Plummer and G. Scott of the "Upper Paleozoic Ammonites in Texas" (*Bull. Univ. Texas*, 3701, 1937, 13-516). The phylogeny of several of the families is established, and important modifications in the classification of the ammonites are found to be necessary.

The "Upper Cambrian and Lower Ordovician Trilobita and Ostracoda from Vermont" are systematically described by P. E. Raymond (*Bull. Geol. Soc. Amer.*, XLVIII, 1937, 1079-146). The *Apatokephalus* stock of trilobites is found in the Upper Cambrian in Vermont, and seems to have appeared earlier in North America than in northern Europe.

F. Raw discusses the "Systematic Position of the Olenellidæ (Mesonacidæ)" (*Journ. Paleont.*, XI, 1937, 575-97), which, he claims, should be elevated to the rank of a separate order, in view of their unique possession of a specialised metaparial grade of head plan, and of their separation from mesoparial and proparial trilobites by the loss of the dorsal facial sutures. These structures can be correlated with the early adoption of a shallow burrowing mode of life, for which the body-form in most of the genera is well adapted.

The British Valentian fauna is so little known that W. F. Whittard's investigations on the trilobites of Shropshire marks an important advance (*Ann. Mag. Nat. Hist.*, ser. 11, I, 1938, 85-140).

Carboniferous trilobites are the theme of works by V. Weber (*Paleont. U.S.S.R. Monog.*, LXXI, 1, 1937, 1-160) and J. M. Weller (*Journ. Paleont.*, XI, 1937, 337-46). The latter shows that many of the American species have been derived from a primitive form typified by *Phillipsia*, and that the most complete series of evolutionary changes are exhibited by the pygidia.

An important insect fauna of Liassic age has been found in Ferghana, Turkestan (A. V. Martynov, *Trav. Inst. Paléont. Acad. Sci. U.R.S.S.*, VII, 1, 1937, 1-180 and 181-232), where the Protorthoptera and the Meganisoptera are shown to extend up into the Jurassic. The author considers that the Ferghana fauna is essentially an Angaran fauna, differing mainly in the presence of a considerable admixture of Australian or Indo-Australian elements.

BOTANY. By PROFESSOR E. J. SALISBURY, D.Sc., F.R.S., University College, London.

No. 17 of the *New York State Museum Handbooks* (1937) consists of a series of articles by various authors dealing with the vegetation survey of Alleghany State Park. This is an area of over 150 sq. kilometres which was formerly occupied by forest but was despoiled by lumbermen so that hardly any of the original vegetation remains. The semi-natural communities that have resulted from rejuvenation give, however, a fairly complete idea of the climax types. On the better-drained ground this climax would appear to have been high forest of Beech (*Fagus grandifolia*) and Sugar Maple (*Acer saccharum*), whilst Hemlock (*Tsuga canadensis*) was also an important feature, especially at lower levels where, too, Oaks and Poplar are frequent species. Comparison of existing frequencies with those indicated by surveyors' records of the primeval forests of 1798 would appear to show that the chief effects of the replacement of virgin plant communities by seminatural ones are marked decreases in the frequency of the Beech and Hemlock, of *Pinus strobus* and *Castanea dentata*. The first three of these are species of the final phases and their diminution can be attributed to the effects of lumbering, but the almost complete disappearance of the Chestnut is the consequence of attack by fungal disease. On the other hand increases are shown by the Sugar Maple and *Acer rubrum*, the latter a definite pioneer species. Attention should be called to the concluding section, which is concerned with administration policy and stresses matters, that are equally cogent in this country, such as the importance of recognising the proper relations between recreational, scientific and economic aspects and the need for proper biological control, as for example in the matter of the preservation of fallen timber, to ensure alike the preservation of the plants and animals which they furnish with food.

Data respecting the average length of life of some desert perennials and changes in the desert flora over a period of thirty years are furnished by F. Shreve and A. L. Hinckley in the October number of *Ecology* (18, 463-78, 1937). The observations were made in the grounds of the Desert Laboratory and show a moderate constancy in the number of large perennials, but a steady increase in the plant population as a whole, especially as regards the small woody perennials. The following average spans of life are indicated: *Cercidium microphyllum*, more than 200 years; *Ferocactus wislizeni*, ca. 130 years; *Fouquieria splendens*, ca. 60 years; *Encelia farinosa* and *Franseria deltoidea*, under 22 years; *Podophyllum gracile* and *Riddellia Cooperi*, over 7 years; *Sphaeralcea grossularifolia*, under

7 years. There is thus a wide range of life span even amongst the perennials of a single plant community. As regards the changes in frequency, the most striking were the increased numbers of individuals of *Franseria deltoidea* from 19 in 1906 to 169 in 1936, whilst *Mendosa scabra* exhibited a decrease from 65 in 1906 to 46 in 1929, the number rising again in 1936 to 71.

In a recent paper by O. A. Bushnell and W. B. Sarles (*Soil Science*, **44**, 409, 1937) experiments are reported upon the root nodule bacteria of 44 wild species of plants. Most of these are allocated to the well-known cross-inoculation groups of the Cowpea ; Pea and Vetch ; Robinia ; Amorpha ; Lupin ; Medicago ; Trifolium ; and Strophostyles. The chief interest in these results attaches to several species which could not be assigned to either of these groups and amongst which were several species of *Astragalus*. If further study should confirm the suggestion that the nodule organisms of this genus do not belong to any of the commoner and widespread strains, this may perhaps be an important factor in bringing about the localised character of the distribution of members of this genus.

The species *Nicotiana tabacum* and *Nicotiana rusticum*, though alike in having a haploid chromosome complement of 24, yield hybrid offspring which have an unbalanced chromosome complement and are in consequence self-sterile. D. Kostoff (*Proc. Indian Acad. Sci.*, B, V, 237-44, 1937) treated 81 germinating seedlings of such hybrids by centrifuging, with the object of inducing doubling of the chromosomes. One of the treated plants produced a single branch in which the chromosome complement was 96 (amphidiploid) and the flowers on which proved to be self-fertile, whilst those on the other branches of the plant with $2n=48$ were self-sterile. The offspring resulting from the selfing of the flowers on the amphidiploid branch were either markedly self-fertile, markedly sterile or partially so. The same author records a fertile plant with 80 somatic chromosomes resulting from a cross of *Nicotiana multivalvis* ($2n=48$) and *N. suaveolens* ($2n=32$), presumably an amphidiploid and perhaps induced by high-temperature.

The parthenocarpic development of fruits has been induced in several species by Gustafson, and by Hagemann in *Gladiolus* by the application of growth-promoting substances to the styles. Gardner and Marth (*Bot. Gaz.*, **99**, 184, 1937) now report similar parthenocarpy resulting from the spraying of holly plants in bloom with growth-promoting substances and also by adding these to the soil. Spraying was also efficacious in producing parthenocarpy in strawberries, but not with grapes or even apples.

The embryo development of *Erythronium* and *Calochortus* is described by P. Guérin (*Ann. des Sci. Nat.*, XIX, 255, 1937), who records in the former genus the normal occurrence of polyembryony. The massive proembryo gives rise to from two to four embryos, of which all but one abort.

A study of pure cultures of diatoms by F. Gross (*Phil. Trans. Roy. Soc.*, B, 228, 1-47, 1937) has produced evidence that the centric diatom *Ditylum Brightwelli* requires the interaction of three factors in order to stimulate the formation of resting spores. These factors are, firstly, exhaustion of the medium of nutrient substances as indicated by their formation taking place when the density of the diatoms per unit volume attains a certain value, namely 1000 cells per c.c. of culture medium. Secondly, a temperature below 10° C., and indeed subjecting cultures to the temperature of an ice-box caused high rates of spore formation. Thirdly, low light intensity. When the two last factors obtain, as in autumn and winter, resting spore formation takes place at night, although followed by their germination during the succeeding day. The continuous diminution in size of the frustules was observed in cultures of eight species. Below a certain minimum the diatoms perish, unless the size be restored by auxospore formation. This latter process takes place only when the cells are below a certain size and is the more readily induced by conditions of deficient nutrition the smaller the individuals concerned.

The auxospores are formed by the flowing out of the protoplasm from between the two halves of the frustule, and young auxospores showed the presence of one large and two small nuclei, suggesting a reduction division. In *Ditylum* no microspores take part in the process.

The mycorrhizal relations of the Ericaceæ have been the subject of much controversy. Dr. Rayner claimed that in *Calluna* the fungus extended to all parts of the plant, even to the seeds, thus ensuring infection of the succeeding generation. It was further claimed that such infection was obligatory for the successful growth of the Heather. The infection of the aerial organs has been denied by Christoph and by Freisleben; moreover, Knudson successfully cultivated *Calluna vulgaris* in aseptic cultures in the absence of the fungus. The problem has been recently investigated in the genus *Rhododendron* by H. D. Gordon (*Ann. Bot.*, N.S., I, 593) who finds no evidence for the presence of the fungus in the aerial organs, and indeed concludes that it is confined to the roots. Furthermore the association would appear not to be obligatory, since seedlings were grown for months in the absence of infection. In *Rhododendron*

ambiguum grown under normal conditions the first sign of infection did not appear till six weeks after the sowing of the seeds. Such facts appear to be consistent with the view that the fungus is an innocuous parasite.

ANATOMY.—A study of the development of the spiral elements of *Ricinus communis* by Miss F. M. Scott (*Bot. Gaz.*, **99**, 69, 1937) shows that they arise from uninucleate procambial cells which subsequently become multinucleate. These cœnocytic cells attain a length of from 90 μ to 2500 μ and may contain as many as twenty-three nuclei. The development of the cellulose spiral appears to be rapid and to occur more or less simultaneously throughout the element. The contents do not break down till after lignification of the spiral. The elements do not show any trace of septa and may therefore represent an advanced stage of specialisation of the vessel in which septa formation has been phylogenetically lost.

ZOOLOGY. By EMERITUS PROFESSOR W. GARSTANG, M.A., D.Sc. ; E. B. FORD, M.A., B.Sc., J. A. MOY-THOMAS, M.A., and B. W. TUCKER, M.A., The University, Oxford.

DUBOSCQ and TUZET (*Arch. Zool. Exp.*, **79**, 1937, 157–316) have now published their fully illustrated account of the early development of Calcareous Sponges, the preliminary notes on which were summarised by us last October (Vol. XXXII, 320). In addition to what was there reported, we draw attention to important observations on the maturation and fertilisation of the egg, the description of four eye-like organelles perradially arranged, "*en croix*," in the larva, and to the comparison drawn with a parallel case of reversal of surfaces in *Volvox*.

Doris R. Crofts (*Phil. Trans.*, B, **228**, 1937, 219–68) gives a thorough account, admirably illustrated, of the development of the Gastropod *Haliotis*. Eggs and sperms are ejected through the shell-holes above the mantle-cavity, and fertilisation is external. The eggs sink, and the embryo begins to rotate within the vitelline membrane about eight hours after fertilisation. It hatches an hour or two later as a true trochophore, with only the slightest indication of Molluscan characters. The larvæ are pelagic for at least two days, and are phototropic, revolving on an axis through the apical pole, which lacks the ciliary tuft of *Patella*. During this period mantle, shell and foot undergo their development, and the first stage of torsion is accomplished. Prior to torsion the hind-gut undergoes its ventral flexure, the mantle grows forwards ventrally, enclosing the foot rudiment from behind, and the shell assumes its primary exogastric curvature. A strong retractor muscle develops

early from the right mesoderm band, and extends from the shell dome to the dorsal side of the velum, making a wide arch round the right side of the visceral hump. On the second day a weak retractor also develops on the left side, but remains dormant for about five days. After metamorphosis and commencement of creeping habits, this muscle connects with the shell and enlarges greatly as the columellar muscle of the adult. The commonly accepted view that the larval (right) retractor becomes the columellar muscle is thus erroneous.

Torsion begins at about thirty hours after fertilisation. "The asymmetrical velum retractor muscle is mainly responsible for the rapid first 90° of torsion. . . . The second half of torsion is brought about slowly by differential growth. The development and migration of the columellar muscle is mainly responsible for it." The difference between some of the author's results and those of Smith on *Patella* (abstract in this Journal, XXXI, 1936, p. 329) are carefully examined, and the paper concludes with a lucid discussion of the various theories of Gastropod torsion.

G. H. Foxon (*Ann. Mag. N.H.* (10), **18**, 1936, 403-19) has made an important correction of Lankester's account of the movement of Annelid parapodia. In creeping movements, the right and left parapodia of any one somite move to and fro alternately, not simultaneously, as Lankester thought, and each backward movement is accompanied by a protrusion of acicula and chaetae, which are retracted at the beginning of each forward swing. In swimming, of course, the body itself is thrown into undulations, and the phases of parapodial movement are distributed over an increasing number of somites, but, as long as the eye can follow, always with the two appendages of each somite in antagonistic phase. The walking movements of Centipedes, but not Diplopods, follow the same plan.

E. J. W. Barrington (*Phil. Trans.*, B, **228**, 1937, 269-81) breaks new ground in *Amphioxus* by a physiological study of its digestive system. Extracts of the pharynx yield no digestive enzymes, but these (amylase, lipase, and protease) are all produced through most of the gut region. From the range of pH values, they must be essentially similar to those already known in Tunicata, but an unexplained acidity of the contents of the "liver" seems to exclude this organ as a seat of actual digestion or absorption. Physiologically the gut is divided by a clear region, the "ilio-colon ring," into two regions. The mid-gut in front, with its diverticulum (the so-called "liver"), is essentially secretory, the hind-gut mainly absorptive. The ilio-colon ring itself is strongly ciliated, and sets the pharyngeal food-rope rotating, the direction being downwards

on the left side and upwards on the right, i.e. anti-clockwise to an observer from behind (not in front, as inadvertently stated on p. 272). A "dorsal ciliated tract" causes a backward current from midgut to anus, and a peculiar "lateral tract" (better "dorso-lateral") on the left side anteriorly collects stray particles that enter outside the food-rope or are carried forwards by midgut eddies. It conveys them backwards and dorsally. The net result of these and other arrangements is to drive digestive secretions from the diverticulum and midgut on to the rotating food-rope in the gut lumen, and to detach partly digested particles from the rope and transfer them to the epithelium of the hindgut, which is said to ingest them. It is claimed that *Amphioxus* resembles the higher Chordates in possessing an extra-cellular digestive mechanism, but differs from them in completing the digestive process intracellularly. The "liver" is held to have no special claim to that title, and to be comparable with certain anterior diverticula at the base of the oesophagus in Australian *Ammocoetes*. These forecast a digestive organ more nearly of the pancreas type.

Two things puzzle one after reading this obviously careful study. Firstly, how is it that the rotation of sticky particles should subserve entanglement and concentration in the pharynx, but disentanglement and dispersal in the ilio-colon ring? Secondly, not a word is said about the actual food of *Amphioxus*. Its reactions to a diet of gold, carmine, and ink leave us still in the dark as to how it tackles diatoms, which presumably form a large proportion of its normal food. There seems to be no evidence that such things are intracellularly digested.

Clausen and Mofshin (*Anat. Rec.*, 67, suppl. 1, 1936, 104) have shown by oxygen consumption studies that the pineal eye of the lizard, *Anolis carolinensis*, acts as a photoreceptor, though the eyes are the essential organs in this connection. Clausen and Poris (*Anat. Rec.*, 69, 1937, 39-50) find an increase in spermatogenic activity in this reptile as a result of artificial illumination, but the stimulation is *greater* when the pineal is removed. Hence this organ is evidently not one of the primary avenues of light reception serving towards testis activation, but on the contrary seems to behave to some extent as an inhibitor in this connection.

Remarkable results have been obtained by Lack and Lockley (*Brit. Birds*, 31, 1938, 242-248) in homing experiments with Manx Shearwaters (*Puffinus puffinus*). Ringed individuals of this pelagic species taken from known nesting burrows on Skokholm island, Pembrokeshire, were released in various parts of the British Isles and made successful returns from such places as Birmingham and

Evesham in the centre of England and the Isle of May in the Firth of Forth, the special interest of the latter case lying in the fact that while the distance to Skokholm overland is about 340 miles a return by sea could only be made by a much longer and roundabout journey of some 800 miles. Successful returns were also accomplished after releases off Spain and off the Faeroes, involving distances of 600 to over 700 miles, and finally one of two birds released at Venice on July 10 was found back at its burrow a fortnight later. The latter is undoubtedly the most extraordinary case of a homing return by a bird yet recorded. Venice is some 660 miles (overland) outside the range of the species, 930 miles from Skokholm overland and 3700 miles (or 2600 if it crossed Italy) by the sea-route, which both from the general habits as well as the observed behaviour of experimental birds on release, appears much the more likely to have been followed. Hypotheses of visual memory, difficult enough in various other cases of homing, become absolutely impossible here and the physical basis of this kind of orientation remains a mystery. Experimental work is being continued.

GENETICS.—J. B. Hutchinson and R. L. M. Ghose (*J. Genet.*, **34**, 1937, 437–46) have provided a comprehensive summary of the genetics of “crinkled dwarf” in cotton. The importance of this mutant, which is normally recessive and controlled by a single factor-pair, lies in the critical evidence which it provides for the study of dominance modification. These authors have now proved that the condition has arisen in *Gossypium hirsutum* by mutation, a fact which disposes of one of the two difficulties felt by Harland in accepting without reservation the theory of dominance modification by selection postulated by Fisher. His second objection, that the heterozygotes are not at a disadvantage compared with the normal form, also appears to be removed. A re-examination of his data shows that the vigour of the heterozygotes had probably been maintained by unconscious selection.

H. Grüneberg (*ibid.*, 169–89) has obtained a test case demonstrating the position effects of genes. He has studied a gene in *Drosophila* producing very rough eyes when situated in an inverted segment of the X-chromosome, and he finds that its effect disappears when the original alignment is restored.

K. Oguma (*ibid.*, 247–64) has now provided additional evidence to show that the female is the heterogametic sex in the Reptilia. It may be, therefore, that this condition had been attained by the common ancestor of birds and living reptiles, of course after the separation of the mammalian line. He has shown that the chromosome number of the Soft-shelled turtle (*Amyda japonica*) is 64 in

the male and 63 in the female. In the latter sex, X is evidently present without a partner. The use of the WZ terminology, employed by this author, should be abandoned.

G. W. Beadle (*Genetics*, **22**, 1937, 587-611) has made a further important contribution to the study of physiological genetics. He has analysed the origin of the diffusible substance now found to be concerned in the production of most of the eye colours of *Drosophila*.

VERTEBRATE PALÆONTOLOGY.—Watson (*Phil. Trans.*, B, **228**, 49, 1937) has given an entirely new account of the structure of the Acanthodians. These fishes, which have hitherto been generally considered to be nearly allied to the cartilaginous Elasmobranchs, are shown to be more closely related to the earlier Arthrodires, Macropetalichthyds, Rhenanids and Pterichthyds. The Elasmobranchs form a concise group, whose evolution starts in the Upper Devonian with primitive forms like *Cladoselache*, whereas the Acanthodians are first found in the Upper Silurian and are far more specialised than the Elasmobranchs before the latter appear. The Acanthodians have no specialised spiracle but a fully formed hyomandibular gill-slit, and in later forms a mandibular operculum. Watson believes that this condition is general in the Arthrodira, Macropetalichthyds, Rhenanids and Pterichthyds and consequently classifies them with the Acanthodians in the class Aphetohyoidea. In addition to the unspecialised hyoidean gill slit, the group is characterised by the possession of dermal and perichondral bones.

Westoll (*Nature*, **141**, 127, 1938) describes a new skull roof *Elpistostege*, which he believes shows characters intermediate between Osteolepids and early Amphibia. Accordingly he has produced a new system of comparison between the Crossopterygian fish skull roof and the Amphibian. The essential difference is due to a relative shortening of the neurocranium posteriorly, which he believes to cause a similar shortening of the dermal bones in this region. He thus compares the frontals of Osteolepids with the parietals of Amphibia, and makes corresponding changes in the nomenclature of the other bones.

Aldinger (*Medd. Grønland*, **141**, 1937) has described the Actinopterygian fish fauna of the Permian of East Greenland. The interest of his paper lies mostly in a bold and not altogether unsuccessful attempt to classify the Palæoniscoids into families by the microscopic structure of their scales.

ENTOMOLOGY. By H. F. BARNES, M.A., Ph.D., Rothamsted Experimental Station, Harpenden.

HYMENOPTERA.—Olfactory conditioning in an endoparasitic insect, the ichneumonid *Nemeritis canescens*, and its relation to the

problem of host selection has been studied by W. H. Thorpe and F. G. W. Jones (*Proc. Roy. Soc. Lond.*, B, **124**, 1937, 56-81). Normally this ophionine parasitises the larva of the meal moth *Ephestia kühniella*, but in America there is a race which attacks the large wax moth *Galleria mellonella*. No difficulty was found in securing oviposition on the larvæ of the small wax moth *Meliphora grisella* provided that the *Nemeritis* was first placed in close contact with *Ephestia* larvæ so as to become contaminated with the smell of that host. Once the eggs were laid normal development proceeded. The olfactory responses of *Nemeritis* reared in this way were compared, in an improved McIndoo olfactometer, with those reared on the normal host *Ephestia*. The experiments showed that there is a strong germinally fixed tendency to follow up the odour of *Ephestia*, but in addition those reared on *Meliphora* showed a significant attraction to *Meliphora*. Although some changes in the olfactory responses may be brought about merely by exposing the *Nemeritis* to contact with *Meliphora* larvæ for a period immediately on emergence, the whole of the effect of rearing on *Meliphora* is not due to this. There is besides some conditioning effect resulting from the influence of the host acting during the pre-imaginal period. This demonstration of the possibility of "pre-imaginal olfactory conditioning" is of great interest because of its possible importance in starting evolutionary divergence. It is emphasised that the change of host does not result in any change of colour, size or structure of the adult parasite.

Some years ago Salt tested the validity of the random distribution theory on field data concerning superparasitism of *Cephus pygmaeus* by *Collyria calcitrator*. He concluded that the females did not distribute their eggs at random but they exerted some discrimination. Marjory G. Walker (*Parasitology*, **29**, 1937, 477-503) has analysed this field data in relation to relevant details of the life histories of both insects in an attempt to find something in the activities of the parasite to account for its observed distribution in its host. After discussing certain activities of the parasite, this investigator worked out various hypothetical distributions and found that the most satisfactory one is obtained if one assumes that the probability of superparasitism occurring varies with the proportion of the parasitised hosts. It was also found, that a shortage of hosts at a time of parasite activity may cause a high degree of superparasitism and so give an erroneous impression of the parasite's ability to discriminate.

As has already been noted (SCIENCE PROGRESS, XXXI, No. 123, 1937, 523) certain species of *Coccophagus* have a peculiar form of

bisexual development, the females developing only as primary endoparasites and the males only as secondary ones either ecto- or endoparasitically. A full account of this has now appeared by S. E. Flanders (*Univ. Calif. Publ. Ent.*, 6, 1937, 401-22). Here it is shown that while the developmental histories of the females of different species are very similar, those of the males may differ radically. In five species considered the first instar of the male is of four types, planidium, modified planidium, teleaform (in two species) and of the common hymenopterous type. The importance of a thorough understanding of this phenomenon may be expected to be of great importance in the successful utilisation of these parasites in biological control work.

S. M. Cendana (*Univ. Calif. Publ. Ent.*, 6, 1937, 337-400) has contributed materially to the knowledge of the biology of the genus *Coccophagus* in a study of five Californian species. The members of this genus are parasitic on nondiaspidine coccids. One particular point is that inhibited hatching of the larvæ, which is described for the first time, is due to the failure of the female parasite to mate before oviposition. This phenomenon occurs in two of the species under investigation.

There have been many investigations on the effect of parasites on their hosts. Recently G. Salt (*Parasitology*, 29, 1937, 539-53) has dealt with the effect of the host on its parasite. In this paper the prevalence of *Trichogramma semblidis* on the eggs of the alder fly, *Sialis lutoria* at Cambridge in 1936 is discussed and full descriptions of this parasite are given. Both forms of the dimorphic male differ constantly in several characters but neither is imperfect or degenerate. Breeding experiments showed that it is principally the species of the host that determines which form of parasite shall emerge. Males reared on *Sialis* are of the apterous form while those reared on three species of Lepidoptera are of the winged form. The only other case of dimorphism in Hymenoptera that has been subject to experimental control is that of *Apis mellifica*. In this case also differences in the kind of nourishment taken during their development results in the alternative forms.

P. Marchal (*Ann. Epiphy. Phytog.*, 2, 1936, 447-550) has made a notable investigation into the biology and development of various biological races of *Trichogramma* occurring in France. There are apparently two groups: one represented by *T. cacæciæ* and allied forms which have light colours and in which parthenogenesis by thelytoky dominates; the other by *T. evanescens* and allied forms which have dark colours and in which bisexual reproduction dominates with arrhenotokous parthenogenesis also occurring.

DIPTERA.—The physiology of digestion in insects until a few years ago was little understood. Wigglesworth in 1927 found that the cockroach, which has a mixed diet, secreted enzymes which enabled it to digest practically all kinds of food. Then the same worker studied a strictly blood-feeding insect, *Glossina*. In this case only proteolytic enzymes were found. Hobson carried our knowledge further when he demonstrated that larvæ of *Lucilia* contained enzymes capable of digesting proteins, fats and carbohydrates. Thus in each case the enzymes found were those best suited to the food habits. D. N. Roy (*Parasitology*, **29**, 1937, 150–62) has recently studied digestion in *Gastrophilus equi* larvæ which feed in the stomach of horses. Here the salivary glands secrete only a proteolytic enzyme, while the mid gut secretes amylolytic, proteolytic and lipolytic enzymes. This is in accordance with the view that the larvæ feed not on blood but on the fluid products (protein, fats and carbohydrates) of digestion in the horse's stomach.

The corpora allata in *Chironomus* and *Tipula* have been described and their occurrence in other Diptera Nematocera briefly reviewed by E. T. Burt (Proc. Roy. Soc. Lond., B, **124**, 1937, 13–23). In addition, Weismann's ring of cyclorrhaphous larvæ is described in *Calliphora* and reasons are given for concluding this organ is the modified and fused corpora allata. Finally, Weismann's ring is considered as the probable seat of origin of the hormone discovered by Fraenkel. This hormone was shown by him to control pupation.

R. C. Muirhead Thomson (*Parasitology*, **29**, 1937, 273–358) has made a contribution to our knowledge of the biology and larvæ of anthomyid flies in a study of those species whose larvæ are found in cow-dung. This community includes purely saprophagous and coprophagous species, semi-carnivorous ones and obligative carnivores. Special attention has been paid to a comparison of the oviposition habits and eggs of the females and the development and structure of the larvæ both in relation to food habit and to the systematic position of the adults.

A comparative account of the larvæ of *Trichomyia urbana*, *Psychodes albipennis* and *Phlebotomus argentipes* by D. Keilin and P. Tate (*Parasitology*, **29**, 1937, 247–58) has shown that the larvæ of the first mentioned are quite distinct both in their wood-boring habit and in their morphology from other psychodid larvæ.

A general paper on the nature, epidemiology and control of sheep myiasis in Britain has been written by J. MacLeod (*J. Comp. Path. and Ther.*, **50**, 1937, 10–32). This is a summary with references of the present knowledge concerning maggot fly pests.

OTHER ORDERS.—An outstanding contribution to the systematic knowledge of the family Isotomidae of the Collembola has been made in a posthumous monograph by J. W. Folsom (*Smithsonian Institute, U.S. Nat. Mus.*, Bull. 168, 1937, 144 pp.). Although nominally dealing with nearctic forms there are twenty-one species and nine varieties which are also palearctic in distribution. J. Ford (*J. Animal Ecol.*, 6, 1937, 98–111) has been studying fluctuations in natural populations of Collembola and Acarina. The characteristic observed was a fluctuation during the winter with increases in November and December and again in early and late February. This may be compared with Ionescu's results in woodland in Roumania where he found a double fluctuation with peaks in October and January in Collembola and Acarina. It is apparent that such fluctuations do not appear to be explained by environmental changes. The February minimum is shown to correspond with a period of high evaporation rate. During this period contrary winds destroyed the tussock structure which the population inhabited.

Colour vision in the triungulin larva of the Strepsipteron *Corioxenos antestiae* has been investigated by T. W. Kirkpatrick (*Proc. R. Ent. Soc. Lond.*, (A) 12, 1937, 40–4). Their faculty of distinguishing colours, especially black and orange, is apparently of direct benefit to them by tending to increase the number of individuals that succeed in attaching themselves to a potential host. In Tanganyika Territory this insect is a common parasite of the Pentatomid *Antestia lineaticollis*, whose nymphs are predominantly black and orange.

PHYSICAL ANTHROPOLOGY. By L. H. DUDLEY BUXTON, M.A., D.Sc., Exeter College, Oxford.

IN our studies of the most primitive types of man we are for the most part dependent on odd, and often very incomplete specimens, whose position in the evolutionary series it is often difficult to determine. Thanks, however, to good fortune and the energy and foresight of the late Davidson Black, we have in *Sinanthropus* a series both of adults and of children and can therefore assess which characters are really typical and which are individual. It is natural, therefore, that a very extensive literature has grown up round "Peking Man." The latest contribution by Dr. Franz Weidenreich (*Journ. Roy. Anthrop. Institute*, LVII, 1937), who succeeded Black in the Cænozoic laboratory at Peiping, is one of extreme interest and importance. Weidenreich was the first to assert the relationship between *Sinanthropus*, *Pithecanthropus* and *Javanthropus*. *Pithecanthropus* was found in Java many years ago by Dubois and

was for a long time the only representative of this primitive group of hominids, while *Javanthropus* is a more recent discovery, also coming from Java. The other very primitive types of man known are *Eoanthropus*, found by Smith Woodward in Sussex, but not considered by Weidenreich in the paper under discussion; *Rhodesian Man*, to which reference will be made later, is a skeleton found in South Africa which presents many characters which link it up with *Neandertal Man*, although many authorities have held somewhat diverse opinions about it, and it has even been associated by Dubois with *Sinanthropus* and *Javanthropus*. Discussing the form of the cast of the interior of the brain case, Weidenreich believes that neither *Javanthropus* nor *Rhodesian Man* is similar to *Sinanthropus*, for both display the characteristically flattened frontal lobe, with the broad and indistinct rostrum, characteristic of *Pithecanthropus* and of recent man. In this respect *Sinanthropus* is much more primitive than *Pithecanthropus*. This general form of the frontal lobe is confirmed by a study of the details, and the arrangement of fissures and convolutions of *Sinanthropus*, as far as they can be recognised, resemble much more those of the chimpanzee than of modern man. Weidenreich is of opinion that, after having considered all the peculiarities of the endocranial appearance of *Pithecanthropus* on the one hand and of *Sinanthropus*, *Javanthropus* and *Rhodesian Man* on the other, it becomes clear that there does not exist such a fundamental difference between *Sinanthropus* and *Pithecanthropus*, nor is there a closer connection between *Sinanthropus* and the other two as Dubois suggested. *Sinanthropus* is the most primitive and *Pithecanthropus*, in spite of the small size and the low brain case, represents a more advanced stage of evolution. On the evidence of the general morphology of *Sinanthropus*, *Javanthropus* and *Rhodesian Man* Weidenreich concludes that there is no doubt that *Rhodesian Man* must be grouped with the *Neandertal* series. It has nothing in common with *Sinanthropus*, and he has come to the opinion that in relation to evolution the other two must be put in the following order, *Javanthropus* the most advanced, *Sinanthropus* (not *Pithecanthropus*) the most primitive. He believes that the configuration of the forehead and its relation to the frontal torus is decisive. In *Pithecanthropus* and *Javanthropus* there are two large frontal air sinuses, one on either side. In *Sinanthropus* the air sinuses are only several small holes strictly confined to the interorbital region. It is true that frontal air sinuses extending over the orbital roof are found in recent man and in the apes, so it is impossible to decide whether their presence or absence is more primitive, but he believes that the smallness

and restriction to the interorbital part is surely a specific character of *Sinanthropus*, and their largeness and extension in *Pithecanthropus* and *Javanthropus* prove the close relationship of the two types. Because of the uniformity in general absence of large sinuses and their restriction and the peculiar form of the forehead and torus, Weidenreich considers the smallness of the frontal sinus and the compactness of the frontal torus as a real primitive character for hominids. He adds that, according to Turner, in 30 per cent. of Australian aborigines the frontal sinus is absent. Turner gives no data about its restriction. An examination of some recent skulls by the present writer, after reading Dr. Weidenreich's article, would seem to suggest that the absence, or restriction, of the frontal air sinuses is certainly more frequent among the primitive races of man to-day than among the more advanced, but that the whole question needs further examination before allowing it as a specific character.

Dubois considers *Pithecanthropus* to be a giant Gibbon. Weidenreich suggests that the Trinil thigh bone is definitely gibbon-like. The teeth which were found at Trinil show not the slightest resemblance to gibbon teeth. We cannot of course be certain that skull-cap, teeth and thigh bone belong to the same animal. Weidenreich then confining his attention to the skull-cap holds that in the endocranial cast there is a fundamental difference between the gibbon and *Pithecanthropus*. He states that on all the facts Dubois' conclusion that *Sinanthropus* and *Javanthropus* are identical and *Pithecanthropus* is a giant ape is untenable, quite the reverse being true. The latter being in a more advanced stage of evolution than *Sinanthropus*, indeed he goes so far as to suggest that *Pithecanthropus* may be a small female of *Javanthropus*; it will be remembered, as stated above, that geographically this is not impossible. The new finds of Peking Man show great variability and the size of the brain links these primitive forms with Neandertal man. The striking fact of the *Sinanthropus* material is that very primitive and far advanced features are found side by side, either in the same individual or in different ones. On the other hand only one specimen of *Pithecanthropus* is available and that incomplete. In point of fact, then, we still are in considerable doubt as to the exact evolutionary position even of those few specimens of early hominids and we do not know at all their real relationship to modern man.

In regard to subfossil man—if we call by awkward name relics of men who resemble modern man but lived in very ancient or definitely prehistoric times—physical anthropology is definitely

in the collecting stage, and the accumulation of material goes on apace. It is particularly unfortunate, therefore, as has been previously stated in these columns, that anthropologists cannot come to a better concordat on method. The whole question is briefly reviewed by C. B. Davenport in the *American Journal of Physical Anthropology*, XXXIII, No. 1, 1937, under the title of *Anthropometry*. He concludes that the average technique of the anthropometrist is a slap-dash thing and that it is little wonder that it becomes difficult to compare different results of different anthropometrists. After giving examples of these differences, he sums up the position by saying that the whole study of racial differences and the genetics of such differences is badly handicapped, and research on the physical development of children can hardly be said to be on a scientific basis. It is, however, to be noted that the Biometric school have recognised this fact and have done and are doing much to counteract this tendency, not only by standardising their own technique, but also by taking not only their own measurements but also using the technique of others when it happens to be standardised, so that results of very different schools of workers can be compared.

The need of standardisation is seen especially in the numerous and valuable papers which give the results of field workers in various parts of the world. It is impossible to discuss these in detail, but a selection of one or two may be given which show points of special interest. W. D. Hambly in Vol. XXV, No. 1, of *Field Museum of Natural History, Anthropological Series*, discusses some skeletal material from San José ruin in British Honduras. The skeletal fragments from Mayan graves are usually too broken for examination, but Dr. Hambly has made a careful record of the few obtained from the San José site which will be of great value as a help in building up a longer series of ancient Mayan remains. At the same time he has compared his material and that from Baking Pot with living Maya material and concludes that the ancient and modern types belong to the same population. The point is of interest as showing the persistence of a physical type associated with considerable change of culture. A. J. D. Meiring in his paper on the "Wilton skulls of the Matjes River Shelter" (*Soölogiese Navorsing van die Nasionale Museum, Bloemfontain*, Deel 1, Sesde Stuk) adduces evidence for a very different type of persistence. The author believes that the culture associated with the remains may be roughly considered to be synchronous with the Azilio-Tardenoisian and a direct continuance with the European Aurignacian. We are, however, concerned not with the archæological details

but with the physical type of these ancient men in South Africa. Meiring first compares these people with the Bushmen and concludes that there are no affinities; he finds similar differences between them and the Hottentots and Bantu and considers that the presence of the Wilton folk in South Africa must be due to an immigration either from or through North Africa. After a careful comparison with ancient European remains, he concludes that there is a marked similarity between his specimens and the "Cro-Magnon-Solutrean group." He believes, after making due allowance for the smallness of the numbers in each group he finds, that the only differences between the South Africans and the Europeans is that the former have shorter faces, broader foreheads and crania which are slightly higher in the vault, but he emphasises the slightness of the differences. He makes it clear that he does not wish to imply that the ancestors of the Wilton folk ever lived in Europe but rather that they belonged to the same North African stock which also lived in south-western Europe at the end of the Pleistocene period, and he believes that the closest parallel is between the Wilton people and the Cro-magnon of Europe.

Turning to recent man, Dr. Steadman in his Presidential address to the British Society for the Study of Orthodontics (*Dental Record*, 1937) discusses malocclusion among the Tasmanian Aborigines and compares their dental health with that of modern civilised man. From an examination of their skulls he concludes that they were almost free from periodontal disease and suffered little from caries, although "here and there abscesses appeared with the usual swollen face." Their jaws were well developed and in early life the occlusion was normal. With advancing years, however, owing to the grit and dust in their food, there was considerable attrition, and in some cases the lower jaw was able to slide forward and possibly as the result some of them developed an edge-to-edge bite. He concludes, on the basis of his examination, that this absence of disease was due to the fact that they did not enjoy the "sticky, sugary, carbohydrate food" of modern civilisation. On the other hand their dental trouble, the attrition of the teeth, has ceased to exist amongst us because we eat our food, sticky though it may be, without a top dressing of dust and grit.

Further effects of modern industrialism are discussed by G. H. Daniel, "Changes in the racial character of the population of the Llandeby district" (*Journ. Roy. Anthropol. Inst.*, LXVII, 1937). This important paper discusses the racial characters of those people whose forebears were living in the district which lies 16 miles north of Swansea, astride the northern border of the South Wales anthracite

belt, before 1850, and an "industrial sample" who represent immigrants. He concludes, after a series of measurements on living persons, that the industrial sample have consistently larger measurements than the pre-industrial sample, and he finds that there are definitely significant differences in the case of stature, forebreadth and lower jaw breadth and possibly in nasal facial height. In qualitative observations he found that the industrial population is darker in both hair and eye colour. On the other hand, he found no significant difference in the homogeneity of the two populations. This latter is an interesting point. There is every reason to believe that homogeneity is the result of isolation. On the other hand, here we find both the older population and the later immigrants equally homogeneous, or if we look at it from the other point of view equally heterogeneous. We must admit as true the conclusion of the author that even in pre-industrial days there was a continual movement of the population. It is interesting to note that work done by the Department of Social Studies in Oxford, communicated to the present writer by Mr. Gilbert, shows a wide range of original homes for the industrial immigrant population of that city, whereas according to figures collected by the writer, the non-industrial population round the city, although it shows an equally wide range ultimately, going back several generations, actually has its places of origin very differently grouped from those of the industrial group. Daniel analysed the occupations of the pre-industrial and industrial samples and found that there was an actual difference in their occupations and thinks that it can be explained on the basis of their racial differentiation. There is, in point of fact, an excess of dark-haired people engaged in mining, whereas on the other hand there is an excess of fair-haired people engaged in non-industrial work. He considers that the explanation of a different racial make-up of the two sections of the population may be strengthened by considering sociological factors, which he explains as meaning those implied by the term "social inertia." This finding is very interesting in comparison with the writer's data already alluded to, where in rural Oxfordshire among people of the *same* non-industrial occupations there was no racial difference between the immigrants and the "aborigines."

NOTES

Artificial Oyster Production (J. H. O.)

In a recent publication on "Experiments in the Breeding of Oysters (*Ostrea edulis*) in Tanks . . ." *Fishery Investigations*, Series II, Vol. XV, No. 4, 1936, by H. A. Cole from the Government Fisheries Experiment Station at Conway, an account is given of efforts to establish a process of tank breeding sufficiently simple and reliable to be of use to the practical oyster cultivator.

A variety of experiments dating from 1919 have made it clear that larvæ can grow and settle in tanks under a considerable range of conditions of salinity, temperature, alkalinity and water circulation. Hence later experiments have been directed to food supply, nature of the food and condition of the parent oysters. To this end a very promising experiment was carried out in 1936. Freshly dredged oysters were added in April to two tanks both of which contained ordinary sea water, one only being enriched with crushed crab-meat following an established technique. The growth of probable larval food, especially nanno-plankton, was closely studied, along with the physical conditions, and related to the growth and settlement of the oyster larvæ. The enriched tank gave the largest settlement of larvæ ever experienced on tiles in the Conway tank, while the control tank gave only a meagre spatfall. The settlement in the enriched tank was on a commercial scale; if this can be repeated without failures, the problem of the commercial artificial production of the European oyster is solved. The successful rearing of freshly extruded larvæ to the settling size in a bell-jar containing only a Chrysomonadid flagellate offers further proof of the approach to ultimate success. The settlement of freshly extruded larvæ reared to full size in untreated outside water in small vessels is a triumph to the credit of the Port Erin workers; unfortunately in this case the kinds of possible food-organisms are unknown. There is therefore still some doubt as to the particular food-organisms which oyster larvæ can utilise. The Conway experiments indicate strongly that micro-flagellates sufficed under the conditions existing, while the Norwegian investigations indicate that green nanno-

plankton may have been the chief food in the oyster-pots, a circumstance that Cole considers doubtful. It seems possible that some other factor or factors may control the utilisation of the food-organisms. Young oysters on a sample of the tiles carrying the heavy Conway spatfall were transferred to the sea with cage protection and survived and flourished, proving their viability by attaining commonly a size comparable with naturally fallen spat.

The results of new experiments on a large scale in the future on feeding larvæ on cultures of known organisms will be awaited with great interest by oyster-cultivators. The Ministry have in the meantime justified their establishment of oyster-breeding experiment stations.

Miscellanea

The New Year Honours list included the following names well known in scientific circles : *K.B.E.* : Mr. T. Rigg, director of the Cawthron Institute, Nelson, New Zealand. *Knights* : Mr. W. Palin Elderton, chairman of the British Insurance Association ; Mr. W. Reavell, lately president of the British Engineers' Association ; Dr. T. F. Sibby, vice-chancellor of the University of Reading ; Dr. C. McM. Wilson, dean of St. Mary's Hospital Medical School ; Mr. D. R. Wilson, H.M. Chief Inspector of Factories. *C.M.G.* : Dr. J. D. Tothill, director of agriculture, Uganda Protectorate. *C.I.E.* : Dr. C. W. B. Normand, director-general of observatories, Government of India. *C.B.E.* : Mr. J. B. Beresford, secretary of the University Grants Committee ; Mr. A. L. Hetherington, assistant secretary of the Department of Scientific and Industrial Research ; Dr. J. W. Mellor, lately director of the British Refractories Research Association ; Dr. E. C. Snow, joint honorary secretary of the Royal Statistical Society. *O.B.E.* : Mr. R. A. Farquharson, geologist in charge of the water boring scheme in Somaliland ; Dr. R. S. G. Knight of the Royal Naval Cordite Factory, Holton Heath ; Mr. F. Leney, lately curator, Norwich Castle Museum ; Mr. W. B. Rimmer, acting director of the Solar Observatory at Mount Stromlo, Australia ; Ram Chandra Srivastava, director of the Imperial Institute of Sugar Technology, Cawnpore ; Dr. V. E. Wilkins, principal, Ministry of Agriculture and Fisheries.

Mr. W. M. H. Greaves, chief assistant of the Royal Observatory, Greenwich has been appointed to be Astronomer-Royal for Scotland in succession to Prof. R. A. Sampson.

The gold medal of the Royal Astronomical Society has been awarded to Dr. W. H. Wright, director of the Lick Observatory,

Mt. Hamilton, California for his spectrographic work. Bronze medals have been awarded to Mr. P. M. Ryves for his observations on variable stars and to Mr. F. J. Hargreaves for his general contributions to astronomy.

The Symons Memorial gold medal of the Royal Meteorological Society has been awarded to Dr. G. M. B. Dobson and the Duddell medal of the Physical Society to Prof. H. Geiger.

Lord Rayleigh has been elected president of the British Association for the meeting which is to be held in Cambridge during the week August 17-24. The sectional presidents are as follows: A (Mathematics and Physics), Prof. C. G. Darwin; B (Chemistry), Prof. C. S. Gibson; C (Geology), Prof. H. H. Swinerton; D (Zoology), Dr. S. W. Kemp; E (Geography), Prof. T. Griffith Taylor; F (Economics), Mr. R. F. Harrod; G (Engineering), Prof. R. V. Southwell; H (Anthropology), Prof. V. Gordon Childe; J (Psychology), Dr. R. H. Thouless; K (Botany), Prof. W. Stiles; L (Education), Mr. John Sargent; M (Agriculture), Prof. R. G. Stapledon.

Dr. B. A. Keen has been elected president of the Royal Meteorological Society, Mr. J. E. Barnard, president of the Royal Microscopical Society, Prof. E. A. Milne, president of the London Mathematical Society, and Dr. L. J. Spencer, president of the Mineralogical Society.

We have noted with great regret the announcements of the death of the following well-known men of science during the past quarter: Major E. E. Austen, formerly keeper of the Department of Entomology, British Museum; Sir Jagadis Chunder Bose, physicist; Dr. G. A. Boulenger, F.R.S., zoologist; Prof. G. A. Buckmaster, physiologist; Sir James Crichton-Browne, F.R.S.; Mr. T. Nelson Dale, geologist, formerly of the Geological Survey of the U.S.A.; Dr. N. G. Dalén, N.L., physicist; Prof. L. N. G. Filon, F.R.S., mathematician; Prof. C. Gravier, of Paris, marine zoologist; Prof. A. Hutchinson, F.R.S., mineralogist and lately master of Pembroke College, Cambridge; Prof. Alfred Lodge, mathematician; Prof. H. Molisch of Vienna, botanist; Prof. E. L. Nichols lately of Cornell University, physicist; Prof. G. H. F. Nuttall, F.R.S., biologist; Mr. W. H. Parker, director of the National Institute of Agricultural Botany, Cambridge; Mr. G. Philip, chairman of Messrs. George Philip & Son, geographical publishers; Prof. W. H. Pickering of Harvard, astronomer; Dr. A. B. Rendle, F.R.S., botanist; Prof. J. S. Štěrba-Böhm of the University of Prague, chemist; Prof. Otto Warburg of the Hebrew University, Palestine, botanist.

Nature (Jan. 8) contained letters from P. Kapitza (Moscow) and Allen and Misener (Cambridge) dealing with the viscosity of liquid helium II at temperatures of the order of 2° K. It appears that the viscosity of helium in this state is extraordinarily low so that it is difficult to obtain non-turbulent flow in a capillary tube. Indeed, neither in a disk flow method devised by Kapitza nor with the fine long capillaries used by Allen and Misener was it possible to obtain laminar motion. Allen and Misener found that the velocity of flow changed only slightly for large changes in the pressure head so that neither lamina nor ordinary turbulent flow occurred in their experiments and it was considered possible that the liquid slips over the surface of the tube. It was agreed, however, that the viscosity is not greater than 10^{-9} gm. cm. sec. $^{-1}$ i.e., less than a ten-millionth of that of water at 20° C.

The English International Institute Examinations Enquiry Committee which owes its existence to the Carnegie Corporation, the Carnegie Foundation and the International Institute of Teacher's College, Columbia University, has issued a book by Sir Philip Hartog entitled *A Conspectus of Examinations in Great Britain and Northern Ireland* containing "a sketch showing the width and variety of the field covered at the end of the first third of the twentieth century by the examination system" in the countries concerned. The bulk of the book is devoted to details of the examinations which mark the ends of the various stages of education from the elementary school to the University degree, but other matters are dealt with, e.g. the "procedure adopted for examinations conducted under statutory authority for admission to specified professions and callings" of very diverse kinds including the law, midwifery and taxi-cab driving. It is easy to appreciate why "no attempt is made to indicate the complex regulations which govern a choice of optional subjects" but it follows that the book loses much value as a work of reference. The arrangement of the examinations with which the Universities are concerned is curious. In each case the examinations conducted by the University of Oxford come first, next those for which the University of Cambridge is responsible and lastly in *alphabetical order* the examinations conducted by the other universities!

The catalogue of the Atom Tracks Exhibition held in the Science Museum in London last winter may be obtained from the museum or from H.M. Stationery Office, Adastral House, W.C.2, for 7d. (post free). The exhibition included C. T. R. Wilson's original

expansion apparatus, lent by the Cavendish laboratory, and nearly a hundred photographs covering the whole field of cloud track investigations from 1911 to 1936. The catalogue contains a plate illustrating four of these photographs (including that obtained by Anderson on August 2, 1932, which first gave definite evidence for the existence of the position). For nearly all the others a precise reference is supplied and in every case there is an adequate explanation both of the photograph itself and of the circumstances in which it was taken. The pamphlet, compiled by Dr. F. A. B. Ward, provides an admirable summary of atomic and sub-atomic physics and is well worth reading even by those not fortunate enough to see the Exhibition itself.

The *Bell Laboratories Record* has of late been largely devoted to articles of purely technical interest. Attention may, however, be drawn to the description of a vapour-pressure humidostat and thermostat embodying an ethyl chloride psychrometer in the issue for November 1937. A new machine, called the isograph, for finding the roots of polynomial equation is described in the December number and a micrometer for measuring the thickness of compressible materials such as paper in the issue for January 1938. The rotatable end of this micrometer is connected to the screw only by a light helical spring. The rotatable member is turned until the end of the screw comes up against the object to be measured and then the turning is continued until the spring is compressed by a definite amount indicated by the alignment of marks scribed on the rotating head and on the screw barrel. In this way the object between the jaws of the micrometer is subjected to a definite pressure and the estimate of its thickness is not dependent on the operator's judgment.

The *Bell System Technical Journal* for October 1937 contains an article by E. J. Murphy and S. O. Morgan which gives a most excellent qualitative account of the various factors which determine the dielectric constants of different materials for different frequencies of the impressed potential difference. These factors may be classed as instantaneous and absorptive. The former operate at all frequencies, the latter at radio, audio or power frequencies. Instantaneous polarisations are completely formed in 10^{-10} sec. or less and are due to displacements of electrons within the atoms and to the displacement of ions in an ionic lattice or of atoms in a molecule or molecular lattice. Absorptive polarisation is due to the orientation of polar molecules (the Debye polarisation) and to interfacial polarisation in heterogeneous media such as paper, laminated plastics

and ceramics. All of these, except that due to the displacement of electrons, are affected by temperature.

The twenty-second annual *Report of the Committee of the Privy Council for Scientific and Industrial Research*, opens with a tribute to the inspiration and enthusiasm with which the late Lord Rutherford guided the work of the Advisory Council during his seven years of office as chairman. The Report records substantial progress in practically all directions of the Department's work, both in the researches carried out by the research establishments of the Department itself, and in the laboratories of the research associations, formed on a co-operative basis in various industries under the Department's auspices. The associations' financial resources encouraged by the present conditions of grant, maintain an upward tendency. The aggregate income subscribed by industry has now practically reached £250,000, and the Government's grants amount to nearly half that sum.

A new research association has been formed by the pottery industry, the first since 1931. The Pottery Manufacturers' Federation has guaranteed an income of £10,000 per annum for at least five years and the Department has agreed to make a grant of £5,000 a year so that the association starts its work with an adequate income.

The total number of grants held by students-in-training in the academic year 1936-37 remained unchanged at 121, but of these 81 were new grants, an increase of 13 over the previous year. No fewer than 60 of these grants were held by chemists—an unusually large proportion of the whole. The number of grants for special investigations increased from 51 to 59 mainly owing to an increase of 6 in the number made for physics.

Turning to details of general interest it may be noted that the Fuel Research Board is investigating a process for "dust-proofing" coal by spraying it with small quantities of a suitable oil and is enquiring into the possibilities of improvements in the domestic grate. The Food Investigation Board carried out a very complete investigation of the new system of refrigeration developed in the Ditton Laboratory of the Department for use on food ships used in the Australasian trade. In this system air is cooled externally and then driven rapidly in a vertical direction through the cargo, finally passing through hollow walls enclosing the cargo space to prevent heat leakage through them. The results of temperature measurements made on board ship during an actual voyage showed that the temperature was maintained uniform throughout the cargo space within 1° F. which is less than the 2° F. margin of uncertainty

as to the best temperature to be maintained in *e.g.* a cargo of apples.

Work on the gas storage of home-grown William and Conference pears showed that these pears respond to gas storage even better than apples. Trials are being carried out with strawberries, grapes, broccoli, peas, plums and asparagus. Experiments with poultry have shown that after 5 months' storage at -10° C. in boxes lined with a composite aluminium foil-greaseproof paper the birds after thawing were undistinguishable in appearance and palatability from freshly killed specimens. (The *Report* does not, however, state the time which elapsed between the thawing and cooking of the test samples—a matter of first importance to the consumer). The Food Manufacturers' Research Association has been concerned with meat products. In particular, efforts are being made to find a gelatine jelly which, when used to fill the spaces between pieces of meat packed in glass containers, will not melt at summer temperatures. The blackening sometimes seen in tins used for canned meats is also under investigation. It is due to tin sulphide (and iron sulphide if the iron is exposed by the fracture of the tin coating) and although it does not make the product in any way harmful it does make it less attractive. The sulphur is liberated from the meat proteins and it is hoped to find how the different canning processes affect the evolution of the sulphur so that their effect may be reduced to a minimum. The Wool Industries Research Association continues to devote attention to methods of minimising shrinkage. The *Report* contains no reference to the new process which was devised by the Association some three years ago and which, in 1936, was reported as being ready for tests under semi-manufacturing conditions. The Linen Industry Research Association is working on a process for spinning a new type of linen yarn which has a soft bulky nature like wool with the advantages of the washability and non-shrinking of linen.

These are only a very few of the points dealt with in the 190-odd pages of the *Report* which may be obtained from H.M. Stationery Office for 3s. net.

The *Annual Report*, 1937, of the Director of the Imperial Institute suggests that the Institute is emerging very successfully from the critical position in which it was placed by the economic depression in 1929-30 when, but for the generosity of private benefactors, it was in danger of closing down altogether. Support from the Union Government of South Africa and a donation of £1000 from Sir Robert Hadfield has made it possible to bring the Mineral Resources

Intelligence Section almost up to full strength and the publication of the very valuable monographs on minerals, which was resumed in 1936, was continued in 1937. The staff was reorganised in 1935 and last year the contribution of the Institute to the pension fund was increased from 5 to $7\frac{1}{2}$ per cent. of all salaries. The Galleries have been rearranged on a system which links the various Empire Courts in a geographical sequence and the exhibits rearranged to appeal especially to the school parties which formed the major part of the 600,000 visitors in the year under review. A Press Publicity Officer was appointed in 1936 and his work combined with that of the Director is serving to make the Institute and the facilities it offers better known throughout the Commonwealth.

The U.S. Department of Commerce has published a third edition of the Bureau of Standards Handbook entitled *Code for Protection against Lightning* (H 21. Price 15 c. from the Superintendent of Documents, Washington, D.C.). The Handbook contains detailed instructions for the protection of buildings of various kinds and an excellent account of the origin, characteristics and effects of lightning. There has also been issued a fifth edition of the pamphlet dealing with *Magnetic Testing* (Circular C 415, price 10 c.) which "gives general information regarding magnetic quantities, the magnetic characteristics of materials, the principles employed in magnetic testing apparatus, and a brief discussion of the theory and application of magnetic analysis," all in thirty-three pages with a thirty-fourth devoted to the essential references.

The National Research Council, Washington, has issued a third edition of the *Handbook of Scientific and Technical Societies of the United States and Canada*. This is intended as a guide to those scientific and technical societies, associations and institutions of the United States and Canada which contribute to knowledge or which further research through their activities, publications or funds. Each entry contains the name and address of the Society, and brief information as to its object, membership, meetings, publications, etc. For information about societies not appearing in the *Handbook* users are referred to an Appendix, which contains short notices of lists of societies obtainable from other organisations. The price of the book is \$3.00 in paper, \$3.50 in cloth.

We are asked to announce that the Head Office and Showrooms of the Cambridge Instrument Company have been removed to 13, Grosvenor Place, London, S.W.1.

ESSAY REVIEW

PHILOSOPHY AND SCIENCE. By SIR ARTHUR EDDINGTON, F.R.S., Plumian Professor of Astronomy in the University of Cambridge. Being a Review of **Through Science to Philosophy**, by HERBERT DINGLE. [Pp. viii + 363, with 18 figures.] (Oxford : at the Clarendon Press ; London : Humphrey Milford, 1937. 15s. net.)

It is recorded that Archbishop Davidson, in conversation with Einstein, asked him what effect he thought the theory of relativity would have on religion. Einstein answered, "None. Relativity is a purely scientific theory and has nothing to do with religion." His hasty evasion is not surprising ; in those days one had to become expert in dodging persons who were persuaded that the fourth dimension was the door to spiritualism. But the answer, which has often been quoted and applauded, can scarcely rank among his more perspicacious utterances. The compartments into which human thought and experience are divided are not so watertight that fundamental progress in one is a matter of indifference to others. For example, natural selection is a purely scientific theory. If in the early days of Darwinism the then archbishop had asked what effect it was likely to have on religion, ought the answer to have been, "None. Evolution by natural selection is a purely scientific theory and has nothing to do with religion" ?

The great change in theoretical physics, which began in the early years of the present century and is still in progress, is a purely scientific development ; but it must affect the general current of human thought, as at earlier times the Copernican and Newtonian systems have done. With one branch of general philosophy, namely epistemology, the connection is particularly intimate. Epistemology is concerned with the nature of knowledge ; and the nature of that part of our knowledge which takes the form of a description of a physical universe has at all times been a theme of contention between rival philosophers. I do not think that any school of philosophy is prepared to wash its hands of the physical universe—as a "purely scientific" matter—and leave the physicists to make what they like of it. On the other hand, physicists can scarcely be denied a hearing on a subject which concerns them so

intimately ; and I do not think their " intrusion " into philosophy through this approach is a matter for surprise or caustic comment.

Professor Dingle is one of many who have attempted to elucidate this meeting-point of physics and philosophy. " Through Science to Philosophy " is a happy title ; but, of all the recent books on the subject, I should be inclined to single out Dingle's as the one to which it is least apt. From the beginning the outlook is that of critical philosophy ; and the reader must face some 200 pages of discussion of such subjects as Consciousness, Experience, Truth, Words, Reason, etc., before he is deemed sufficiently inoculated against modern heresy to be allowed contact with current scientific ideas. Thus the order of thought seems rather to be " through Philosophy to a right comprehension of Science." I think that this treatment misses one of the most significant features of the present drawing together of philosophy and science ; theoretical physicists, through the inescapable demands of their own subject, have been forced to become epistemologists in the same way that pure mathematicians have been forced to become logicians. Most amazingly it has been found that the study of the nature of scientific knowledge is not an idle luxury, and that it is actually an aid in the search for knowledge to know the nature of that for which we seek. It is this *compulsory* abandonment of the naïve realism of the older scientific outlook which has appealed to most modern writers ; but Dingle scarcely recognises the existence of a route by which the scientific study of the universe has, through its own practical development, independently reached conclusions comparable with those of philosophy.

Dingle rather goes out of his way to give the impression that his hand is against every man. Doubtless some of his contentions will arouse opposition ; but his insistent magnification of imperceptible differences seems to me exaggerated. At the outset he assumes the rôle of protector of the plain reader bewildered by the paradoxical utterances of scientific experts. On pp. 19-20 we are given an " extraordinary miscellany of absurdities " collected from Dirac, Eddington, Planck, Bohr and Jeans. Here are two samples from Dingle himself, which seem not unworthy to be added to the collection :

I should not say " I know that the sun is 93 million miles away " (p. 173)

He [Bertrand Russell] has missed the essential point that physics is not concerned at all with planets (p. 93).

Has it not occurred to Professor Dingle that some of the statements which he pillories may be less perplexing and perturbing to the

ordinary man than an assurance from a professor of astrophysics (who *ex officio* is "not concerned at all with" stars) that the astronomically measured distance of the sun is not scientific knowledge?

The present reviewer naturally turned with special interest to p. 344, where Dingle states what he takes to be the root of his dissent from the philosophy of Eddington. The passage which he quotes from my writings is as follows:

The only subject presented to me for study is the content of my consciousness. You are able to communicate to me part of the content of your consciousness which thereby becomes accessible in my own. For reasons which are generally admitted, though I should not like to have to prove that they are conclusive, I grant your consciousness equal status with my own; and I use this second-hand part of my consciousness to put myself in your place.

Dingle's criticism is:

It seems to me that the inconsistency of this passage vitiates the greater part of Eddington's philosophy. It is clear that there is an inconsistency because the other person's consciousness is said to be partly in his own and yet to have equal status with it.

It will be noticed that my statement that "part of the content of your consciousness becomes accessible in my own" is replaced in Dingle's argument by "your consciousness is partly in mine." It seems to me that Dingle has himself created the inconsistency by this substitution. If not, it is natural to enquire which of my three sentences he rejects. Not the first, for he admits (p. 345) that it is a truism. The last? I can scarcely believe that Dingle is trying to argue that his consciousness has inferior status to mine. There remains the middle one. I cannot see what he means by denying that by speech and writing we can communicate our thoughts, so that the "subject for study" originally presented in one consciousness becomes accessible (presented at second-hand) in another.

Having drawn blank here, I had almost despaired of discovering in the maze of argument the fundamental difference which has led Dingle to views contrary, not only to my own, but to those of most other scientific writers. But at last, on p. 297, a clear-cut scientific issue presents itself. Comparatively early in the development of quantum theory, Niels Bohr put forward his correspondence principle which defined the relation between field theory and quantum theory: *the classical field laws are the limit towards which the microscopic laws tend when the number of quanta becomes very great*. I cannot recall that this principle has ever before been challenged; it became incorporated at once as one of the guiding

principles in the development of quantum theory; and in the theory of radiation especially it early justified itself by fruitful results. Astrophysics owes an enormous debt to it. Wave mechanics has accepted it as fundamental. If any principle can be regarded as a pronouncement of modern physics (not merely of "certain physicists") the correspondence principle can. This principle Dingle rejects.

We may leave aside the question whether he is justified in rejecting it. The point is that this cleavage amply accounts for his differences from other writers on scientific philosophy—for his escape from what seem to be the inevitable consequences of the modern scientific outlook. Primarily he introduces it in connection with his defence of determinism. He need scarcely have troubled to add more. In the general retreat of modern physics from determinism, Dingle remains behind because he refuses to follow it in recognising that the classical field laws are not separate rules of causality, but are absorbed into the system of microscopic physics. Dingle himself seems to recognise that this rejection of the unity of macroscopic and microscopic physics is crucial for his philosophy (in so far as it differs from that of other scientists). Conversely, I think his opponents would agree that if scientific evidence for a duality were forthcoming, it would involve wholesale reconstruction of their present ideas.

If it appeared that Dingle had examined the correspondence principle from the scientific standpoint, and after exhaustive study had arrived at the judgment that it could not be accepted, we should not question his right to stand out against authority. Not even the correspondence principle is to be held dogmatically. The question of dogma indeed scarcely arises; for it is the essence of a scientifically grounded philosophy that it has the same force as our scientific beliefs (no more and no less). But I can see no indication that that is the way in which Dingle's doubts have arisen. He has found that one of the principal hypotheses that are guiding the present developments of physics is in conflict with the philosophy set forth in his earlier chapters. Therefore it must be rejected. This is not the kind of argument which appeals much to a scientist, though it is not to be condemned out of hand. I dare say it is not unprecedented for a philosopher to be right. Only I should have felt better satisfied if he had called his book "Through Philosophy to Science."

REVIEWS

PHYSICS

Electricity and Magnetism : An Introduction to the Mathematical Theory. By A. S. RAMSEY, M.A. [Pp. x + 267, with 150 figures.] (Cambridge : at the University Press, 1937. 10s. 6d.)

THE author has added to the list of his well-known volumes on Statics, Dynamics, and Hydrostatics, this text-book on the mathematical theory of electricity and magnetism, which covers the schedule for Part I of the Tripos. It includes the fundamental principles of electrostatics, Gauss' theorem, Laplace's equation, systems of conductors, homogeneous dielectrics and the theory of images ; steady currents in wires ; the elementary theory of the magnetic field and the elementary facts about the magnetic fields of steady currents. There are also short chapters on induced magnetism and induction of currents.

Very little mathematical knowledge, other than some elementary calculus and a few properties of vectors is assumed, and the book is well and clearly written from the mathematical point of view, following to some extent Jean's *Electricity and Magnetism*. From the physical point of view it is not so satisfactory : for instance, the capacity of a conductor is defined to be "the charge necessary to raise it to unit potential when it is alone in the field, or when all other conductors are at zero potential. It follows that the capacity of a sphere is equal to its radius . . ." (p. 49). These two definitions will not give the same value and the capacity of a sphere is not, of course, equal to its radius when surrounded by earthed conductors.

Again, in discussing Maxwell's *displacement* theory the author says that "it is open to the objection that there is no experimental evidence that in dielectrics there is an actual displacement of electricity of the kind described. According to modern views it is preferable to define the vector D solely in terms of the conditions which it has to satisfy . . ." (p. 102). It is curious that Mr. Ramsay should have overlooked the beautiful experiments of Eichenwald (*Ann. Phys.*, 11, 421, 1903) which demonstrated the magnetic field produced by displacement currents.

The author, like Jeans, has fallen into the error of providing a mathematical proof of the superposition of electric fields (p. 74). This depends, and must always depend, upon experiment, and it is of interest to examine at what point it is assumed, for in a mathematical proof it must enter as an assumption.

There are a large number of carefully selected questions to which answers have been provided, and the book should prove of great use both to students and teachers. The fact that the illustrations are not numbered and there is no general index are minor defects in an otherwise well-produced text-book.

G. B. B.

Electricity and Magnetism for Degree Students. By S. G. STARLING, B.Sc., A.R.C.Sc., F.Inst.P. Sixth edition. [Pp. viii + 630, with 449 figures.] (London, New York, Toronto : Longmans, Green & Co., 1937. 12s. 6d. net.)

IN issuing the sixth edition of this well-known text-book the opportunity has been taken of increasing the sizes of page and type. As a consequence the volume makes a much more pleasing appeal to the eye and the lay-out is much improved. No attempt has been made to produce a new book. The section on ships' magnetism has been removed to furnish space for brief accounts of cosmic rays, the neutron, positron and induced radioactivity. There is no doubt that the book in its new dress will play as important a part in the dissemination of systematic knowledge as did the earlier editions.

S. MARSH.

Die Atomkerne : Grundlagen und Anwendungen ihrer Theorie.

By DR. C. F. VON WEIZSÄCKER. [Pp. viii + 214, with 40 figures.] (Leipzig : Akademische Verlagsgesellschaft m.b.H., 1937. RM. 16-, bound ; RM. 14.40, paper covers.)

THE appearance of a number of books in the course of the last year or two on the subject of nuclear theory is a sign of the great interest in the subject and of the increase in knowledge about it. Experiments designed to throw light on the problems concerning the atomic nucleus are being pursued in all countries where research in physics is regarded as important and, to judge from the scientific publications of some of these, research is almost exclusively in this branch. Work on the theoretical aspect of the problems is being carried out with no less energy.

The writer of the book now under review is an authority on his subject, and he has attempted to produce a work which will be of use to both experimental and theoretical workers. In the important sections the basic traits of the phenomenon under discussion are presented first qualitatively and without mathematical aids, and then the quantitative treatment follows. This is an attractive and useful feature of the work. The experimental parts of it are self-contained while a theoretical worker has the physical aspects kept closely before him.

The volume is compact, consisting of four chapters, a very short appendix and some tables.

It begins with a brief outline of the history of the theory of the nucleus and passes on to the experimental results. The second chapter opens with a discussion of the binding energies of nuclei which are assumed to be composed of protons and neutrons and passes in its second part to the theoretical considerations, introducing the conceptions of exchange forces between the heavy particles and the phenomenon of saturation associated with the exchange forces. The third chapter is concerned with the phenomenon of alpha ray decay and nuclear reactions brought about by external agents, transformations by neutrons, charged particles and by gamma rays. The last chapter is devoted to the problem of beta ray decay and brings us to the centre of present-day interest. The neutrino hypothesis is first discussed and its difficulties pointed out. Then follows an account of the principles of the quantum theory of wave fields as a preparation for the theory of beta-ray emission developed by Fermi. This very remarkable theory is

often presented by writers on this subject, almost in the words of its founder. But the author in this case has made an attempt to explain the underlying principles of Fermi's theory in a way which suggests its wider outlook. In his section on the calculation of the probability of beta-ray decay he is not as clear as could be desired. The reader has to examine the statement very closely and has much to do on his own account in order to appreciate the full implications. We would suggest that an enlargement of this chapter would add greatly to the usefulness of the book to students, many of whom are likely to fail to grasp all that this theory contains.

H. T. F.

Atomic Spectra and the Vector Model. By A. C. CANDLER. Vol. I: **Series Spectra.** Vol. II: **Complex Spectra.** [Vol. I: pp. viii + 237, with 4 plates and 142 figures; Vol. II: pp. vi + 273, with 4 plates and 212 figures.] (Cambridge: at the University Press, 1937. 15s. net each.)

THE aim of this book is to present a comprehensive account of present knowledge of the structure of line spectra, expressed in terms of the vector model of the atom. The book includes accounts of the various types of spectra considered primarily in relation to the periodic table, and deals also with such related topics as the Zeeman and Stark effects, hyperfine structure of spectrum lines, quadrupole radiation, and the fluorescence of crystals. It is freely illustrated with diagrams and plates, and contains many valuable tables of data. There is a short bibliography at the end of each chapter, and further references are given in appendices.

The subjects discussed are among those best provided for in current literature, and a new book needs considerable merit to justify its existence. It is perhaps the highest praise one could accord to such a treatise to say that the working spectroscopist will still find it useful, and this may without hesitation be said of Mr. Candler's book; indeed, if the word "indispensable" were ever justifiable, one would be tempted to apply it here. In comprehensiveness and completeness in the provision of useful data, the book would appear to be unsurpassed, and the diagrams, most of which are original, are admirably designed and executed and well serve their purpose of avoiding tedious verbal description. The subject-matter is brought well up to date, and the care which the author has taken to secure strict accuracy, even in matters of secondary importance, may be indicated by a footnote: "Laporte, *Nw*, 1924, 12, 598, attributes this work to Paschen and Landé, but the reference given is inaccurate and the paper does not appear under either name in *Science Abstracts*, 1922-24." Improvements might have been made in a few minor points: thus, economy of explanation, usually a merit in the book, has occasionally been carried too far, as in the abrupt introduction to "quadrupole radiation"; the spectra reproduced look unfamiliar with the greater wave-lengths on the left; and tables are inappropriately designated "figures." But such points are trivial compared with the outstanding good qualities of the book. It represents in condensed form the result of a vast amount of conscientious labour, and will be of the greatest help to all concerned with the analysis of spectra. The printing and general format of the volumes are excellent.

H. D.

Molecular Beams. By R. G. J. FRASER, Ph.D. Methuen's Monographs on Physical Subjects. [Pp. ix + 70, with frontispiece and 22 figures.] (London: Methuen & Co., Ltd., 1937. 2s. 6d. net.)

THIS short monograph is concerned with unidirectional, collision-free beams, consisting of neutral molecules (or atoms) moving with thermal velocities. After describing various methods of production and detection, the author gives an account of the reflection, scattering and diffraction of the beams. The remainder of the book deals with the deviations produced when a molecular beam is passed through inhomogeneous magnetic or electric fields.

Pioneer experiments using such beams were carried out by Dunoyer in 1911 and by Stern and Gerlach between 1920 and 1922; and since then continual progress has been made. The author does not attempt to refer to all the experiments, but he describes the more important work in some detail. The book gives a good summary of the present state of the subject, with descriptions of the experimental methods, interpretation of the results, and many references to original publications.

The deflection in inhomogeneous fields has given much valuable information about atomic and nuclear magnetic moments, dipole moments and atomic polarisabilities; but some of the work is very recent and its interpretation may be modified in the course of time. It should be mentioned that, in order to understand the subjects discussed in this monograph fully, it would be necessary to have or to acquire a considerable knowledge of modern quantum theory.

W. N. BOND.

Alternating Current Measurements. By DAVID OWEN, B.A., D.Sc., F.Inst.P. Methuen's Monographs on Physical Subjects. [Pp. vi + 120, with 80 figures.] (London: Methuen & Co., Ltd., 1937. 3s. 6d. net.)

It is a pleasure to find this book on practical methods of measurement included in the useful Monographs on Physics, especially as it deals with a subject now so important and yet so inadequately treated in the traditional Physics course. The book before us will be particularly valuable to those teachers and others who wish to set up A.C. bridges and wavemeters in the laboratory, because Dr. Owen has drawn upon his wide experience and included numerical examples of actual measurements as guides to choice of standards and the accuracy to be expected.

The first chapter is a brief but very clear summary of the A.C. theory necessary for the understanding of the rest. Low-frequency bridge methods occupy about two-thirds of the book, the remainder being devoted to measurements at radio frequencies. There are chapters on self-inductance, mutual inductance, capacitance, conditions of accuracy in bridge work, and measurements at supply frequencies, including the A.C. potentiometer. The radio frequency measurements include capacitance, inductance, resistance, and frequency, but not current or voltage, which is a pity. A more extended treatment of the valve voltmeter would have been welcome. The diagrams are many but rather reminiscent of blackboard sketches.

There are in existence several large volumes on particular aspects of A.C. measurements, but not one so concise and immediately useful to a non-specialist as Dr. Owen's book, which should find its way into every electrical laboratory.

F. A. VICK.

Noise. By A. H. DAVIS, D.Sc. Changing World Library, No. 6. [Pp. x + 148, with 20 figures, including 4 plates.] (London: C. A. Watts & Co., Ltd., 1937. 2s. 6d. net.)

WE live in a world of greatly increased production of noise, and the demand for cheap buildings unfortunately results in structures less able to isolate the noise produced. On both counts noise, its effects and its possible reduction and exclusion are in the news, and Dr. Davis's book gives an excellent short exposition of the whole matter, ranging from human reactions to noise to its measurement, suppression, exclusion and control.

Most people have a vague idea that efficiency and health are affected by noise and this in itself will modify the effect in their own cases. It is thus important that the experimentally ascertained facts as to adaptation and recovery as here summarised should be known. But even if the ordinary man's view of the detriment of noise is exaggerated still that is no reason, as Dr. Davis points out, for failing to reduce unnecessary noise.

That part of the book dealing with the measurement of noise is particularly acceptable. It is useful to know that instruments are available which will give information of a quantitative character. But the design of measuring instruments is at a comparatively early stage. Some of them, as is pointed out, are not reliable even for what is claimed of them. None will answer all the noise questions to which answers are sought. Those who read the text carefully will not be under any misapprehension as to the limitations of the instruments described, but the casual reader may get the erroneous impression that the problem of noise measurement is now virtually completely solved.

Legal aspects of the control of noise are dealt with in the last chapter. A short bibliography of books more or less suitable for the general reader and a good index add to the usefulness of the book.

G. A. S.

Fluid Mechanics. By RUSSELL A. DODGE and MILTON J. THOMPSON. [Pp. xii + 495, with 267 figures.] (New York and London: McGraw-Hill Publishing Co., Ltd., 1937. 24s. net.)

SHOULD fluid engineering now be represented in a single undergraduate subject or Hydraulics, Aerodynamics, and its other branches be developed separately? Professors Dodge and Thompson seem to favour the former view. Their book opens with four chapters mostly on hydrostatics. Eight chapters follow on flow through pipes, orifices, nozzles, etc., and past immersed and floating bodies. The book closes with four chapters on compressible flow, applications of thermodynamics, dynamical similarity, viscometry, lubrication, etc. Matters touched upon include, besides familiar hydraulic examples, aircraft and ships, tunnels and tanks, cavitation and corrosion, propellers, projectiles and lagged pipes. The authors' suggestion, "... that the instructor can select those subjects which best fit the needs and interests of his students," is unexpected, appearing to detract from the utility of the book, which lies in the collective view given of diverse fluid motion affairs. As would be expected, various sections are too incomplete for separate study. Probably no book of reasonable size could cover so wide a field with the thoroughness necessary to the undergraduate. The present interesting experiment might have been improved by rearrangement and more equable treatment. Early introduction of vorticity and physical

knowledge of the boundary layer would have removed many difficulties ; again, various simple irrotational flow formulæ might well have been proved. Nevertheless, the book deals with many interesting matters and is excellently produced and illustrated.

N. A. V. P.

Storage Reservoirs. By GEORGE BRANSBY WILLIAMS, M.Inst.C.E.
[Pp. ix + 293, with 168 figures, including 24 plates.] (London : Chapman & Hall, Ltd., 1937. 25s. net.)

IN writing *Storage Reservoirs* Mr. G. Bransby Williams has met a well-felt need. Types and the technique of construction have altered so rapidly of recent years that most British works of reference are out of date. Recourse had to be had to American sources of information and while much could be learnt in this way the preponderance of American literature on the subject is perhaps the greatest *raison d'être* for a British treatise. In giving prominence to recent British and Indian practice the book forms a useful complement to existing works.

Many engineering books are unreadable. This can be read and enjoyed. The historical approach to a subject wherever possible adds greatly to the interest. A world-wide outlook is maintained in each section. Finally, the personal touch is not missing.

A large mass of useful information is given concerning rainfall and flood flows in various parts of the globe. The design of gravity, multiple-arch and reinforced concrete dams is adequately dealt with, and the author discourses clearly on the complications attendant on arch dams and earth dams. Guidance on the design of arch dams is badly needed and one wishes that he had not allowed his discretion to prevent him giving typical sound designs for standard cases such as U-, V-, and \sqcup -shaped valleys and discussing the effect of modifying the aspect ratio, undeterred by the present controversial state of the subject. Some idea of the limitations of an arch design is often necessary in the preliminary consideration of type of dam.

Some such guidance is given in respect of other types in a graph showing variation of costs with height. Of these the masonry gravity dam is shown as being by far the most expensive for all heights. If mass-concrete dams are included under "masonry" dams the writer feels that this cannot apply generally. The smaller the height of a dam the greater the relative importance of those elements of the cost which vary linearly with the dimensions, such as shuttering and fixing of reinforcement. Since these are greater in the multiple arch and Ambursen types it follows that there must always be some height below which the mass-concrete gravity dam is less expensive.

In spite of its antiquity there is perhaps no structure concerning which knowledge is less exact than the earth embankment dam. The author, perhaps wisely, refrains from correlating specifically the safe slope of a dam and the properties of the material. It is not clear why the permissible seepage should be specified in terms of velocity as it would appear to depend rather upon the more easily determined upward pressure gradient at the downstream toe.

While the lack of elasticity to deal with excessive floods of the siphon spillway is rightly emphasised, it does not, in the writer's opinion, necessarily follow that it should be used merely in a supplementary capacity. With the high intensity of discharge attainable it may well be that in some cir-

cumstances a siphon spillway of sufficient capacity to cope with "catastrophic" floods would be the economic solution.

Minor features of dams such as fish passes are omitted, probably intentionally. A few printer's errors, particularly in references and formulæ, appear to have escaped attention.

The book is a contribution to engineering literature which will be widely welcomed.

A. H. NAYLOR.

Refrigeration Engineering. By H. J. MACINTIRE. [Pp. vi + 415, with 136 figures, including 7 folding plates.] (New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd., 1937. 22s. 6d. net.)

THE applications of refrigeration to industry, and in particular to comfort cooling and air conditioning, are of quite recent development, and writers of technical literature have not devoted as much attention to refrigeration as to some of the other branches of engineering. A further reason for this neglect may be the comparatively small size of the individual units.

In this book Professor Macintire writes primarily for students who have already taken a course in thermodynamics, and accordingly the description of the standard cycles is reduced to a minimum, although many modern developments, such as "dual compression" have been included. The third chapter deals with refrigerants from the points of view of suitability, effect on design, inflammability, etc. Their properties, including those used chiefly in household installations, such as "Freon," are also quoted, and charts are given of the thermal properties, with pressure plotted against heat. British readers are more accustomed to charts giving heat against entropy, but those in the text are equally suitable for the solution of the standard cycles.

The author has based all his heat transfer calculations on the most recent researches, and avoided as far as possible the more or less empirical formulæ hitherto used for the design of evaporators and condensers. Chapters are given on heat leakage into buildings, practical condenser design, including the cooling of the water supply to the condensers, and pipe work. Adsorption and absorption machines are fully treated in Chapter VIII, which includes a chart to aid the calculation of the amount of ammonia in various aqueous solutions. The question of the partial pressures in the Electrolux system is analysed in detail. Mechanical details, erection, etc., occupy Chapters IX to XI, while the remaining sections are given to the applications of various forms of cooling equipment. Air conditioning and the manufacture of dry ice are amongst these, the former in considerable detail, so that the book may be recommended with confidence not only to the senior student, but also to the practising engineer.

S. S. W.

Elasticity, Plasticity and Structure of Matter. By R. HOUWINK. [Pp. xviii + 376, with 214 figures, including 7 plates.] (Cambridge: at the University Press, 1937. 21s. net.)

OPTIMISTIC as the title of this book may seem, it requires very little qualification to make it an accurate description of the scope of the text, in which Dr. Houwink of the Plastics Department, N. V. Philips Gloeilampenfabrieken,

Eindhoven, has brought together a large collection of experimental data on the mechanical properties (chiefly elasticity and plasticity) relating to a comprehensive list of technically important materials, such as glass, resins, asphalt, rubber, cellulose derivatives, proteins, baker's dough, paints and lacquers, clay and sulphur, with the addition of a chapter by Dr. W. G. Burgers on crystalline substances, which includes a short outline of modern theories of the plasticity of metal crystals.

The book is, however, far more than a mere inventory of published work ; it is a comparative survey, in the light of Dr. Houwink's own extensive and important work on resins, of the whole field indicated above.

The book should be of value to two groups of workers ; those trying to choose the most suitable material for a given purpose, and those engaged in research on the mechanical properties of any one of the materials considered. By showing the investigator what has been done, perhaps from quite a different point of view, on an analogous problem with a different material, Dr. Houwink's book should stimulate research along the most useful lines and will help to counteract the present tendency of research workers to overspecialisation, by broadening their knowledge of related but hitherto quite separate problems.

Dr. Houwink has written a new kind of book, and he has done it well ; his treatment is logical and straightforward, and diagrams clear. The translation (from the Dutch, in which the book was written) is satisfactory.

B. C.

CHEMISTRY

Chemistry, Matter and Life. By STEPHEN MIALL, LL.D., B.Sc., and L. M. MIALL, B.A. [Pp. xii + 296, with 8 plates.] (London : Edward Arnold & Co., 1937. 7s. 6d. net.)

NATURE is the great CHEMIST ; man as chemist is the interpreter of Nature, but who shall interpret the chemist to mankind in general ? It is no easy thing to relate the simple facts of chemistry to the intricate pattern and occupation of daily life. To-day chemistry is all-pervading ; no industrial operation is free from some chemical influence. Sometimes the methods used are akin to the natural prototype, but often they go far beyond, for man's ways are not altogether Nature's ways. To-day a variety of circumstances brings every thinking man into contact with scientific matters and he is almost made to reflect upon them ; the wise ones want to know more. In these days Governments are necessarily concerned with problems of nutrition, plant and animal breeding, and there can be few housewives in this country who have not become vitamin-conscious, if only through the agency of the daily press and its advertisement pages. In like manner the public has become aware that it is mainly chemistry (and perhaps electricity) to which are due the luxuries or extra comforts of modern life as well as the satisfaction of the elementary needs of mankind in food, clothing and shelter. The public are also conscious that chemistry, or perhaps the lack of it, is in large measure responsible for the devastation of the countryside in the older industrial districts, the pollution of streams and the horrors of poison gas and the other ravages of war.

To describe and to explain the background of all these things, the manner in which they have come about, to show how matter is built up from nature's bricks—atoms, molecules, crystals—and to unfold the secrets of plant and

animal life processes is a worthy task for a worthy pen. Dr. Miall and his son have done all this in language, as stated in the Preface, that any educated person can understand, although some of the later chapters of necessity require rather close attention on the part of the reader, a fact which is also noted in the Preface. One notable feature of the book is that it has been written without appeal to the sensational, for there is no synthetic miracle in every chapter and no crescendo of the kind so often associated with the presentation of popular science.

This book in quite a small space offers a surprising wealth of information covering much of present-day chemistry, including a satisfying account of modern views on the constitution of matter and the transformation of radioactive substances and the similar transmutations which can now be brought about artificially. In the later chapters the authors deal with the chemistry of living things, the chemicals needed for the growth of plants and animals, how they are produced and their relationship one to another.

It would appear that Dr. Miall had visualised as readers of this book the informed non-technical public desirous of knowing something of what the science of chemistry means; indeed, the book can be recommended to them. There is more in the book than that, however—it has a message for a wider circle. Chemistry has its theorists; they should see what the world makes of their science. Chemistry also has its practising realists—those who utilise chemistry as an industrial component. For them here is something that is not a college text-book, but a very easy way of going back to school for a short spell. The serious purpose of the book will appeal to the enthusiasms latent in most “older” students, and few such men engaged in chemical industry could fail to profit by reading it.

L. A. J.

Thorpe's Dictionary of Applied Chemistry. Vol. I. By JOCELYN FIELD THORPE, C.B.E., D.Sc., F.R.S., F.I.C., and M. A. WHITELEY, O.B.E., D.Sc., F.I.C., assisted by eminent contributors. Fourth edition. [Pp. xxviii + 703, with illustrations.] (London: Longmans, Green & Co., 1937. 63s. net.)

TEN years have passed since the last volume of the last edition of *Thorpe's Dictionary* was published and in these days of rapid advances in chemical technology so long a period means very considerable changes. The third edition was brought up to date merely by additions and new articles so, in essence, it dated from a still earlier period. The new edition, of which the first of nine projected volumes now appears, is to be entirely rewritten. The volumes are promised at the rate of one a year and an attempt is to be made to keep the whole work as far as possible up to date by introducing new matter in subsequent volumes on subjects dealt with in general articles in earlier volumes. As in previous editions the editors have enjoyed the services of experts in various branches of chemistry, and among a distinguished list one might mention E. F. Armstrong, G. Barger, A. E. Dunstan, E. V. Evans, C. Ainsworth Mitchell, G. T. Morgan, E. J. Parry, A. G. Perkin, F. L. Pyman, L. J. Spencer and F. G. H. Tate. The eminence of the numerous specialists and the reputation of the editors is a sufficient guarantee of the authority of the material, and although the work is called a dictionary it is so by virtue of its alphabetical arrangement, rather than by its treatment of the subjects, for the articles are enjoyable to read despite their conciseness.

Thorpe's Dictionary is so well known that it is unnecessary to indicate its usefulness to the industrial chemist, but there is one class, namely, teachers of chemistry, who could well make more use of it than they do. Industrial methods change with great rapidity these days and the ordinary text-books are soon out of date; indeed, some describe methods of manufacture long obsolete when the book is first published. The young chemist is consequently often rather aghast to find on starting industrial work that the processes they learnt at school and college are no longer in use. Catalytic methods are becoming more and more common, the oxidation of naphthalene by atmospheric oxygen to phthalic anhydride has replaced the sulphuric acid and mercury method and benzoic acid is now prepared by the decarboxylation of phthalic acid. In the United States aniline is made in large quantities by the action of ammonia on chlorobenzene under pressure, using cuprous chloride as a catalyst. From the articles acetylene, acetaldehyde, acetone alcohol one learns that acetylene is being increasingly employed for syntheses and is becoming the chief source of acetic acid, acetone and *n*-butyl alcohol, and may ultimately displace saccharides for the manufacture of alcohol, as some three or four million gallons of alcohol a year are now being produced from this source. In addition, acetylene is largely used in the preparation of vinyl esters for the plastic industry and of chloroprene, the intermediate for neoprene, the most successful of the synthetic rubbers.

In addition to this use of the book, one might venture to suggest that students of chemistry might dip into it as a corrective to the ultra-theoretical treatment of the subject now common in the Universities, as it will supply in a palatable form much valuable information on an aspect of chemistry now much neglected despite its importance in the application of the science to modern life.

Turning to detail, the number of printing errors in the articles read by the reviewer is exceptionally small. There is some overlap between the articles on alizarin and allied dyestuffs and on anthraquinone dyestuffs. In the article on alcohol more attention might have been given to the laboratory preparation of absolute alcohol and in the article on azides only one method of preparation of sodium azide is given, and the statement on the behaviour of this compound on heating is not in accordance with the writer's experience; a cross-reference to the article on azoimide would have been useful, as there methods of preparation of azides are given in more detail. The printing, paper and binding are excellent and the editors are to be congratulated on the eminently successful conclusion of the first stage of their long journey.

O. L. B.

Gases and Metals. By C. J. SMITHELLS, M.C., D.Sc. [Pp. vii + 218, with 145 figures, including 4 plates.] (London: Chapman & Hall, Ltd., 1937. 18s. net.)

THE literature dealing with the interaction of gases with metals has become so voluminous that many an author in attempting to write on the subject might easily be led to the compilation of an unreadable catalogue. Dr. Smithells has resisted this temptation to the utmost and has produced a volume which is at once readable and full of relevant information.

The book is divided into three parts: the first dealing with adsorption, the second with diffusion and the third with solution. In the first chapter,

the theories of adsorption are discussed as impartially as is at present possible. Brief discussions are included on such related topics as surface migration, available surface, "getters," while experimental methods are described clearly and concisely. The second chapter is the first complete account, as far as the reviewer is aware, of the present position of our knowledge about the diffusion of gases through metals. The early data are brought together in a convenient form and Dr. Smithells' own experiments, recently published as a series of papers in the Proceedings of the Royal Society, are given their due prominence. Probably the most useful chapter is the third. Data on the solubility of gases in metals is so widely scattered that its compilation and discussion will do much to bring this aspect of the subject into closer relationship with the matter described in the two preceding chapters.

For the experimentalist this work contains all that he may require for almost any problem—academic or industrial—connected with the behaviour of gases in contact with metals. For the theorist here is a critical compilation of most of the data at present available for checking his speculations.

The book is illustrated by a wide selection of well-chosen diagrams.

H. W. MELVILLE.

Collisions of the Second Kind. By E. J. B. WILLEY, D.Sc., Ph.D., M.Sc., M.R.I. [Pp. viii + 150, with frontispiece and 26 figures.] (London: Edward Arnold & Co., 1937. 10s. 6d. net.)

MUCH of the development of the theory of collision processes in molecular physics and in physical chemistry has been due to the recognition of the type of collision known as that of the second kind. The concept is of fundamental importance for the explanation of a wide variety of phenomena. The process occurs in electric discharges through gases, both in the gas and at the gas-electrode interface. It is intimately bound up with the behaviour of fluorescing substances in the gas and liquid phases. In a more general way it is of widespread occurrence in chemistry, forming the basis of the mechanism of chain reactions and playing an important rôle in unimolecular gas reactions.

This monograph is a timely survey of the subject from the physical and chemical viewpoint. It opens with a thorough discussion of the more physical aspects of the phenomena, namely, the spectroscopic evidence for the rules governing energy transfers between excited molecules and atoms. There is a short chapter on ionisation by electron transfer, which is followed by an account of the emission of electrons and the desorption of gases from electrodes under bombardment from positive ions and metastable atoms. The most exact quantitative information about collisions of the second kind is derived from the quenching of fluorescence of optically excited metallic vapours. Chapter 5 is exclusively devoted to this topic and forms a useful introduction to the last chapter dealing with chemical phenomena. Mercury sensitised reactions are discussed at some length and a few typical chain reactions are treated in order to show how their kinetics may be accounted for by postulating energy transfers analogous to those of the second kind.

The field covered by the book is therefore very extensive and is purposely not exhaustively treated. An excellent bibliography, however, makes it easy to go straight to the original literature.

H. W. MELVILLE.

The Electrochemistry of Solutions. By S. GLASSSTONE, D.Sc., Ph.D., F.I.C. Second edition. [Pp. xii + 551, with 39 figures.] (London: Methuen & Co., Ltd., 1937. 25s. net.)

ALTHOUGH the scope of the book remains unchanged, this new edition contains about 70 more pages than the first edition which appeared in 1930. This increase in size is partly the result of rewriting certain sections in a new and more extended form, especially those concerned with the modern theory of electrolytic dissociation, with modern views on acids and bases, and with overvoltage; and partly the outcome of a thorough general revision of the whole book to conform with developments which have taken place during the last few years. Those who have used the first edition either as a text-book or as a work of reference will have appreciated the clear and effective manner in which the facts are arranged and presented, and the interesting and useful way in which rival theories are correlated and their implications critically discussed. These valuable characteristics are fully preserved in the new edition, and all the new matter (with appropriate references to the literature) has been homogeneously incorporated and brought into relation with earlier facts and theories. In particular, the author continues to show how the development of modern theories affects the quantitative treatment of physico-chemical problems which have hitherto been dealt with on classical lines. A proper discussion of many of these applications is difficult to find elsewhere. The printing and general get-up of the book—including the stouter binding—are highly satisfactory, and the author and the publishers are to be congratulated on the production of this new edition of a book which in the course of a few years has become indispensable to students of physical chemistry and to research workers in wide range of specialised fields.

H. J. T. E.

Volumetric Analysis. By A. J. MEE, M.A., B.Sc. [Pp. vii + 223, with 13 figures.] (London: William Heinemann, Ltd., 1937. 7s. 6d.)

WHILST primarily intended to meet the needs of candidates preparing for H.S.C. and scholarship examinations, this book gives many examples of the use of modern reagents and methods in addition to numerous applications of the older processes. The descriptive chapters give full practical details for about 90 experiments. There follows a list of over 200 practical problems most of which do not require more than two hours for completion. Though no individual would carry out more than a small proportion of the experiments it is well that the wide applicability of volumetric reagents should be realised. There is therefore much to be said for such a breakaway from the traditional limits of a school text-book, but the work is unfortunately marred by a number of errors.

The most serious criticism concerns the treatment of certain theoretical matters. The admitted necessity in an elementary exposition for simplification, even at the expense of truth, does not justify a misleading treatment of difficult topics which could better be omitted. Thus in connection with the possible use of phenolphthalein for the Na_2PHO_4 end point, it is stated that "the addition of sodium chloride greatly increases the sodium ion concentration, and thus represses the hydroxyl ion concentration." This is not only wrong, but is quite incompatible with the postulation of the complete ionisation of strong bases in the main discussion of neutralisation. In connection with the Mohr end point, the statement that no silver chromate

is precipitated until *all* the silver chloride has been thrown down is permissible in an elementary treatment, but to add the phrase "as indicated by the law of mass action" is the reverse of helpful, since the law implies that no species present can ever entirely disappear.

The attempt to illustrate some of the simpler aspects of the theory of neutralisation with the aid of curves is in itself good, but it is most unfortunate that there are so many mistakes in the diagram used (Fig. 5). The curve which purports to illustrate the action of *N* ammonia on *N* hydrochloric acid is quite wrong on the alkaline side, and would more properly represent a *strong* base added to *N/20* hydrochloric acid. There is therefore no possibility of drawing from it the desired conclusion with regard to the correct end point. The curve for weak base + weak acid starts at the value of pH 14, which could only be given by a strong base, and finishes at an impossibly low pH. With reference to this curve it is stated that "There are no rapid changes in pH of this solution as *there is little salt formation*". At the equivalence point, the salt which should have been formed will be *completely hydrolysed*" (reviewer's italics). Actually in the case of *N/10* ammonia + *N/10* acetic acid the hydrolysis at the equivalence point is only 0.55 per cent., and up to the point of 90 per cent. neutralisation it is less than 0.03 per cent. The suggestion that the "little" salt formed in the early part of the titration disappears altogether at the equivalence point is misleading in the extreme.

The inclusion in the list of recommended indicators of two which are very expensive, but not essential for the experiments given, suggests that the needs of schools have not been sufficiently considered. Some of the advice concerning the more common end points is open to criticism. The titration of 0.1 *N* sodium carbonate with acid using methyl yellow should not be carried as far as the "faintly pink" stage. If carbon dioxide is boiled off there is no justification for the use of an indicator with a change so far removed from neutrality as methyl orange, which requires about ten drops of acid per 50 c.c. of solution to change it from yellow to red. Methyl red would be changed almost completely by one drop. Even litmus would be preferable to methyl orange. For the titration of chlorides the use of a comparison flask containing silver chromate but no silver chloride is unsuitable for the 0.1 *N* solutions considered. It would be better to add a slight excess of a chloride to the mixture obtained in the first titration. Subsequently the first noticeable departure from the yellow of the comparison should be taken as the end point. In the main the working details of the newer methods are adequately described. Diphenylamine sulphonic acid is, however, a far better indicator for the iron-dichromate reaction than the older diphenylamine.

Useful attention is drawn to the fact that the purity of many chemicals of analytical quality is liable to differ appreciably from 100 per cent., but the inadequacy of ferrous ammonium sulphate as a primary standard is not stressed as it might well have been. It is significant that manufacturers of repute, who once aimed at marketing a product of 99.9 per cent. purity, have now extended the limits to 99.5–100.5 per cent. The proposal to standardise titanous salts by accurately weighing out iron alum is unsound in view of the usual A.R. purity limits of 99–101 per cent.

Provided due allowance is made for the shortcomings indicated above, schoolmasters who wish to extend their repertoire of volumetric exercises would doubtless find this book useful.

T. B. SMITH.

Methods for the Detection of Toxic Gases in Industry. Leaflet No. 1 : Hydrogen Sulphide. [Pp. iv + 6, with 1 folding plate and including set of Standard Stains.] (London : H.M. Stationery Office, 1937. 3s. 6d. net.)

THIS is the first of a series of pamphlets to be issued by the Department of Scientific and Industrial Research describing standard methods for the detection of toxic gases in industry. In the Foreword it is explained that a Regulation of the Chemical Works Regulations, 1922 (made under section 79 of the Factory and Workshop Act, 1901), prohibits entry into any place which might contain dangerous gas by any person not properly protected until the air has been tested and found safe to breathe. At the request of the Home Office, and with the financial and technical co-operation of the Association of British Chemical Manufacturers, the Department arranged for a series of tests to be developed by the Chemical Defence Research Department to cover some of the gases which are most commonly met with in industry. In most cases, chemical methods involving colour changes have been adopted as best suited to the purpose. Each test is being carefully standardised and tested under practical conditions in actual works, and has been made as simple and straightforward as possible. The complete series of tests will deal with the following gases and vapours: aniline, arsine, benzene, carbon bisulphide, carbon monoxide, chlorine, hydrogen cyanide, hydrogen sulphide, nitrous fumes, organic halogen compounds, phosgene and sulphur dioxide.

The present leaflet, after reviewing briefly the occurrence, poisonous effects, and methods of detection of hydrogen sulphide, gives full instructions for carrying out the test under standard conditions. The method adopted depends on drawing a known volume of the atmosphere under test through a piece of test paper treated with lead acetate, which is fixed by a special attachment to a hand pump. Details of this attachment are given in a scale drawing. Concentrations of hydrogen sulphide from 1 part in 150,000 upwards can be gauged by comparing the colour of the stain produced on the lead acetate paper with a carefully printed colour chart which accompanies the leaflet.

The leaflet, which is in a convenient form and the subject matter of which is very clear and concise, should be extremely valuable not only from the point of view of the chemical and allied industries, but in any circumstances where this very toxic substance is encountered. After reading the short account of the very harmful effects produced as a result of various concentrations of hydrogen sulphide in air, one cannot help feeling that those who are entrusted with the teaching of practical chemistry in schools and colleges would do well to peruse this useful publication with the greatest possible care.

H. W. C.

Lehrbuch der organischen Chemie. By PAUL KARRER. Fifth edition. [Pp. xxiii + 973, with 6 figures, including 1 plate.] (Leipzig : Georg Thieme, 1937. RM. 36.-, bound ; RM. 34.-, paper covers ; with 25 per cent. reduction abroad.)

THE appearance of a new edition of this work a little more than a year after the last is evidence of its popularity. This is not surprising since as a textbook of descriptive organic chemistry it is excellent though not, perhaps,

quite up to date as regards manufacturing processes. On the theoretical side the book follows strictly Kekulé's principles and no attempt has been made to introduce the modern ideas on valency. The present edition contains eighteen pages more than the fourth, slight alterations occur throughout introducing matter published up to the end of 1936, but the main additions are naturally in those subjects in which notable advances have been made recently, for example in vitamins and hormones.

O. L. B.

Food Technology. By SAMUEL C. PRESCOTT, Sc.D., and BERNARD E. PROCTOR, Ph.D. [Pp. x + 630, with 70 figures.] (New York and London: McGraw-Hill Publishing Co., Ltd., 1937. 30s. net.)

THIS book should prove to be most useful information to all interested in any branch of foodstuffs. For the Student the reading is easy to follow, and notes can be readily taken of the sources, classification, composition, properties, and uses of the raw materials, and if deeper knowledge is required on the subject, the most up-to-date books are quoted for reference; the outline of the process of manufacture of various products are so good that one almost expects to read the vital details for the carrying out of the work. Another advantage of the book is to be enabled to compare the American methods and foods with those used and partaken of in England, *e.g.* in the making of bread "the dough mixer is usually jacketed," which method is rarely used in an English bakery. Flour confectionery is briefly mentioned under the heading "Biscuit crackers and cookies," whereas a chapter is devoted to sugar confectionery, which indicates that the former industry is not so much to the fore as in England; nevertheless confectioners' raw materials are extensively dealt with. Then there are the breakfast foods and cereal preparations, and a few words used which are unfamiliar. All the above facts tend to broaden the outlook and excite curiosity.

The authors' inclusion of those fungus diseases, insects, moulds and bacteria, and in many cases their prevention and cure, which are liable to attack wheats, corn and cereal products, vegetables, fruits and meat is a valuable asset. The all-important subject of food preservation is thoroughly explained under the headings of refrigeration, dehydration and an excellent chapter on "Canning."

The reasonable price of the book allows of its recommendation as a text-book for students specialising in foodstuffs and flour confectionery and as a useful reference book to breadmaking and flourmilling students, foods chemists, etc.

MARION CHADWICK.

GEOLOGY

The Mineral Position of the British Empire. [Pp. 166.] (Imperial Institute (Mineral Resources Department) Publication, 1937. 4s. net.)

THE aim of this publication is to outline the status of the mineral industry and the mineral resources of the British Empire during the year 1935, the latest for which statistics are at present available, and to review the changes which have taken place since 1929. The last summary, published in 1931, was based on statistics for 1928, but in the intervening period of depression economic and political readjustments have had a marked effect on the industry. Indeed, all the important metals and minerals except gold clearly show the

effects of the great slump. Most of the book is devoted to a survey of the mineral deposits and mining industries of each Empire country. A preliminary statement concerning the mineral industry of the country is succeeded by a table of output for 1935 and a summary of mineral imports with countries of origin and exports showing destinations. The situation in 1935 is compared with that in 1929, but wherever possible later information is included.

The remarkable endowment of the British Empire in mineral resources is shown in the figures so conveniently summarised. In 1935 the Empire produced nearly 87 per cent. of the world's nickel, 68 per cent. of the world's asbestos, Canada taking the premier position in world production for both these minerals as well as for platinum. As regards gold, in spite of a greatly increased output the Empire proportion fell from 72.7 per cent. in 1929 to 58.3 per cent. in 1935.

A comparison of world and Empire production for twelve essential commodities over the years 1928-35 is conveniently summarised by a series of graphs. The total value of the Empire mineral output during 1935 approximated to £400 million, the United Kingdom contributing nearly 42 per cent., the Union of South Africa 21 per cent. and Canada 16 per cent. The value of the coal output of the United Kingdom represents about 37 per cent. of the value of the whole Empire output of all minerals.

Minerals in which the Empire depends almost entirely on foreign countries include antimony, molybdenum, petroleum, potash, mercury and sulphur, with most of which it is worthy to remark the United States among foreign countries is richly supplied. The general picture presented by this comprehensive survey shows how near the Empire, when considered as a unit, approaches mineral independence.

C. E. T.

Elements of Optical Mineralogy. Part I: Principles and Methods. By A. N. WINCHELL. Fifth edition. [Pp. xii + 263, with 300 figures.] (New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd., 1937. 17s. 6d. net.)

WITH its fifth edition this work maintains its place as the standard textbook of the subject. The fourth edition was reviewed in Vol. XXVII, 1933, p. 535. No great changes have been made in this edition, but it has been found possible to make some corrections and additions without adding to the number of pages. More than sixty new or revised figures have been included, some showing the latest models of polarising microscopes and accessory apparatus. Notwithstanding improvements, corrections and additions, there is a welcome lowering of the price of the book by 3s. 6d.

G. W. T.

Silicate Analysis: A Manual for Geologists and Chemists. With chapters on Check Calculations and Geochemical Data. By A. W. GROVES, D.Sc., Ph.D., D.I.C., F.G.S. [Pp. xxii + 230, with 11 figures.] (London: Thomas Murby & Co., 1937. 12s. 6d. net.)

SUCCESSIVE editions of the classical works of Hillebrand and Washington have been for many years the authoritative guides in mineral and rock analysis, and any new book on the subject—as the one before us—must inevitably present the well-tried methods expounded in these texts. The author of *Silicate Analysis* has, however, taken advantage of recent progress to incorporate improvements in technique and to supply analytical methods

for those rarer constituents which have acquired special importance as a result of advances in geochemical studies.

The book opens with preliminary chapters on equipment, sampling and the common operations incident in analytical work. In the main part of the work—describing the orthodox methods—a clear account is given of the chemistry of the operations, and the actual procedure is printed in heavy type to facilitate reference while work is in progress.

The notes on the analysis of some of the more important silicate minerals are instructive, and it is encouraging to find emphasis laid on the inadequacy of the usual methods for combined water in the case of minerals like epidotes and amphiboles. The estimation of ferrous iron in refractory minerals is referred to in a short paragraph, but it is hoped that the author will give this important problem more extended treatment in a new edition.

The value of the work is enhanced by a chapter on technological applications and by an interesting geochemical discussion on the occurrence of the elements. A speculative foreword provided by Professor Holmes cannot be as strongly recommended as the book itself.

C. E. T.

The Petrology of the Igneous Rocks. By the late F. H. HATCH, O.B.E., Ph.D., and A. K. WELLS, D.Sc. Ninth Edition. [Pp. xx + 368, with 154 figures.] (London: George Allen & Unwin, Ltd., 1937. 15s. net.)

THE eighth edition of this work was reviewed in Vol. XXI, 1927, p. 546. Although as a matter of filial piety the name of the deceased senior author has been retained in the title, to all intents and purposes the book is the work of Dr. A. K. Wells, and it is not the least of his many services to igneous petrology. His co-operation with the late Dr. F. H. Hatch began with the eighth edition, in which many new features were grafted on to the original scheme of the work. Among these new features were chapters on the Consolidation of Magmas, on Cycles of Igneous Activity in the British Isles, and a discussion of the experimental work of the Geophysical Laboratory at Washington in relation to igneous rocks. In the present edition all these topics have been brought right up to date. In particular we should like to recognise the value of the long chapter (Part V, Chapter III) which deals with the history of igneous activity in the British Isles. It forms the only comprehensive statement of the subject since Sir Archibald Geikie's *Volcanoes of the British Isles* (1897) which necessarily was defective owing to limitations of knowledge at the time of its publication. Now, with much of the detail filled in, Dr. Wells has been able to write this authoritative compilation, which constitutes a remarkable vindication of the much-criticised conception of petrographic provinces or co-magmatic assemblages although, as Dr. Wells remarks, many problems connected with the genesis, age and relationships of igneous rocks, still remain. Nevertheless, in the British Isles, along with north-western Europe, we now have the data on which to found valuable generalisations on the distribution and paragenesis of igneous rocks in relation to the tectonics of the regions in which they occur.

In regard to nomenclature Dr. Wells has adhered, in the main, to the decisions of the British Association Committee on British Petrological Nomenclature. In classification, "mode of occurrence" has been superseded

by "grain-size" as a dominant taxonomic factor, and Dr. Wells has adopted the numerical limits of grain-size classes which have recently been suggested by the above committee with, as we think, a notable improvement on the previous classification.

In order to make room for new matter the chapters on the metamorphism of igneous rocks which were included in previous editions have now been omitted as being more appropriate to a volume on metamorphic rocks.

The book is divided into five parts: Origin, Occurrence and External Structure; Constituent Minerals; Consolidation of Magmas, and Textures; Classification; Origin and Associations. The whole work is extremely well done, and there are few points that invite criticism. *Lit-par-lit* structures are rather incongruously mentioned in the paragraph devoted to sills (p. 20). The barbarous hybrid "ophimottling" (instead of the more euphonious *pyroxilophitic*) is retained, as also the still-born term "perknite" for ultrabasic rocks of pyroxenic and hornblende composition. A few Scottish place-names are misspelled, but there appears to be only one notable misprint, namely, " MgCO_2 " for " MgCO_3 " (p. 244). The illustrations are well selected and reproduced, and really illustrate the text.

G. W. T.

A Descriptive Petrography of the Igneous Rocks. Vol. III: The Intermediate Rocks. By A. JOHANNSEN, Ph.D. [Pp. xiv + 360, with frontispiece and 178 figures.] (U.S.A.: University of Chicago Press; Great Britain and Ireland: Cambridge University Press, 1937. 21s. net.)

THE third volume of Prof. Johannsen's great work follows the same excellent lines as the two earlier volumes, the second of which was reviewed in Vol. XXIX, 1934, p. 168. Here, again, is the full scholarly treatment of all relevant topics which characterises the earlier volumes. In the present part five rock families, namely, alkali-syenite, syenite, syenodiorite, diorite, and gabbro-norite, and the auxiliary family of the monzonites, are dealt with in the usual exhaustive manner. There is an interesting digression in connection with the pyroxenes of the gabbro-norite family, showing why extinction angles may appear to be inclined in hexagonal, tetragonal and orthorhombic crystals. A number of new "average" analyses of various igneous types is given. There seems to be an error in the statement (p. 17): "By definition the leuco-kalitrachytes are trachytes which contain potash feldspar forming less than 5 per cent. of the light constituents." There are errors in a few place-names, and it is hardly correct to say (p. 274) that the Giant's Causeway is a continuation of Staffa. The one is in Ireland and the other in Scotland, and the localities are 120 miles apart.

Some of Johannsen's taxonomic and nomenclatorial dicta are certain to be hotly disputed. He retains the term *monzonite* somewhat grudgingly, and states that this name is desirable only in local descriptions of areas where such rock-types predominate. He also recommends the abandonment of the term *trachyandesite*, the name used for the volcanic equivalents of the monzonites. In remarking (p. 298) that the term *tholeiite* is practically obsolete, Johannsen ignores the revived and extended usage of this term in Great Britain to indicate a well-defined series of basic volcanic rocks which includes the over-saturated basalts. The reviewer must also energetically dissent from Johannsen's view that the term *spilite* should be

dropped (p. 300). The author clearly brings out the unexpected point that *porphyrite* is an older term than *porphyry* (p. 82). *Elkhornite* is a new name which is legitimately applied to a labradorite-bearing augite-syenite; but the new term *massafuerite* (p. 335) applied by Johannsen to olivine-rich basalts, is unnecessary, as it duplicates *oceanite*, which was coined by Lacroix and is now extensively used for identical rocks latterly found to be very common in oceanic islands. Notwithstanding his abhorrence of the associational factor in classification Johannsen nevertheless uses this factor to distinguish between alkali-lime trachytes and alkali-trachytes in cases where the rocks contain neither quartz nor feldspathoids (p. 17).

In spite of a few small blemishes the sun of the general excellence of this great treatise is undimmed, and we eagerly await the fourth and final volume, which is to deal with the Feldspathoid Rocks and the Ultrabasic Rocks, when we shall be ready to acclaim Prof. Johannsen as the Rosenbusch of modern igneous petrography.

G. W. T.

Gulf Coast Oil Fields : A Symposium on the Gulf Coast Cenozoic.

By Fifty-two Authors. Edited by D. C. BARTON and G. SAWTELLE.

[Pp. xxii + 1070, with frontispiece, 19 plates and 295 figures.] (Tulsa, Oklahoma: The American Association of Petroleum Geologists; London: Thos. Murby & Co., 1936. \$4.00 or 18s. 6d.)

THIS is a symposium which is intended to supplement the similar volume on the *Geology of Salt Dome Oil Fields*, published by the American Association of Petroleum Geologists in 1926. The present work consists of 44 papers reprinted from the *Bulletin* of the Association. The main advances made in the interval are the recognition of deep-seated salt-domes, and the intensive development of geophysical methods of prospecting. The number of known domes has been approximately doubled by the use of the torsion balance and seismograph. Improved technique on the part of the seismic geophysicist with the reflection method, and the electrical logging of wells, led to the drilling of salt-domes to a depth of 10,000 feet, and an increase in production until in 1935 it reached 123 million barrels. In the Foreword, D. C. Barton states that a great increase in the depth of exploratory wells and of production is a safe prediction. Wells to a depth of 20,000 feet may be mechanically feasible and not impracticably costly by the end of this decade, but certain considerations suggest progressive decrease in the commercial value of deep production with increasing depth.

The volume begins with a Foreword by the senior editor, D. C. Barton, who has also contributed an explanation of the methods of reading an aerial photo-mosaic, an example of which is provided in the Frontispiece, which is a view of the Barber's Hill area in Texas taken at a height of 12,000 feet. Thereafter the volume is divided into three parts: I. General and Theoretical Papers (14 papers); II. Stratigraphy (10 papers); III. Descriptions of Oil Fields and Salt-domes (20 papers). The last-named part is divided into groups dealing respectively with South Texas, South-East Texas, Southern Louisiana and East Texas. An outstanding paper in the first part is that by D. C. Barton on the Mechanics of Formation of Salt-domes; other papers deal with the structures of the Gulf Coast, and the cap-rock minerals of salt-domes. Only the South Texas group of fields includes examples which are either questionable salt-domes or definitely not salt-domes.

The book is a fine example of the printer's art, and the illustrations are clear, informative and well reproduced. There is a full index of 20 pages in double column. The value of this work is not confined to American oil geologists, and specialists in the salt-dome fields of other countries would be well advised to study it.

G. W. T.

BOTANY

Transactions of the Bose Research Institute, Calcutta. Vol. X, 1934-1935. Edited by SIR JAGADIS CHUNDER BOSE, M.A., D.Sc., LL.D., F.R.S. [Pp. vi + 240, with 65 figures.] (London, New York, Toronto: Longmans, Green & Co., 1937. 18s. net.)

THIS volume comprises about a dozen papers on biological and physical researches carried out at the Bose Institute in Calcutta, the former mostly plant physiological studies and observations made with the aid of the sensitive measuring apparatus for which the institute is well known. The papers include experiments on the influence of age on the velocity of transmission of excitation in *Mimosa*; the effect of continuous and intermittent light on the growth of *Cosmos*; the relation between age, water-content and dormancy in the seed of *Cajanus*; the effect of variations of temperature on the respiration of *Helianthus*; chemical analyses of *Trichosanthes*, an Indian medicinal plant; the presence of vitamin C in plant juices, and the movement of ascorbic acid to the embryo of the coconut; and (strange to the ears of the British horticulturist) upon the use of seeds of the various Himalayan *Meconopsis* spp. as a source of oil and manure. There is one anthropological paper on human remains from a Maler cemetery, while the physical papers deal with the spectrum of Zinc in ionisation, the absorption spectra of the alkaline halides in solution and of Zinc and Cadmium halide vapours.

There is an introductory section by the late Sir J. C. Bose, in which he summarises each paper.

One serious criticism to be made is that in many of the biological papers the results must be greatly invalidated by the small number of experiments performed. Thus the relation between leaf age and excitation transmission velocity in *Mimosa* is obtained, if the text is correct, upon observations upon one leaf, confirmed by those upon a second; while results in other papers seem to rest upon observations of four or five experiments. In none of these papers is it stated or inferred that more than these experiments were performed, although this is hardly credible. But if more experiments were performed, then at least some idea of the statistics or even of the mean of the results should have been given.

The physical researches are interesting, and, apart from the above criticism of the biological work, the papers combine to form an interesting volume.

F. Y. H.

Leguminous Forage Plants. By D. H. ROBINSON, Ph.D., B.Sc., N.D.A. [Pp. vii + 119, with 35 figures.] (London: Edward Arnold & Co., 1937. 6s. net.)

As the author explains in the preface, this little treatise is chiefly intended as an elementary text-book for agricultural students and others, and as such it meets a great need, since very few books on crop cultivation have been

published in this country. It deals in a simple and concise manner with all the leguminous forage crops grown in Britain, including the true clovers, medicks, sainfoins, lupins, sweet clover, kidney vetch, birdsfoot trefoil and the pulse crops. The general arrangement is excellent. A chapter is devoted to each genus, while each crop—its general characters, seeds, seedlings, varieties, uses, seed production and chemical composition—is treated separately. The botanical characteristics of the seeds, seedlings and adult plants are given in considerable detail. With the aid of the excellent illustrations, which are a special feature of the book, the reader should experience no difficulty in identifying the various crops at all stages in their life cycles. Though this book contains many excellent features, its usefulness would have been greatly enhanced had more space been devoted to the various practical aspects of crop culture, such as the comparative value of varieties and strains, economic uses, methods of cultivation and of seed production of the various crops. A few minor errors have been noted, but these will no doubt be corrected in the next edition.

R. D. W.

PEDOLOGY

Soil Conditions and Plant Growth. By SIR E. JOHN RUSSELL, D.Sc., F.R.S. Seventh edition. [Pp. viii + 655, with 65 figures, including 11 plates.] (London, New York, Toronto: Longmans, Green & Co., 1937. 21s. net.)

SOIL students of twenty-five years ago welcomed the first edition of this book for two main reasons. First, because it gave, more concisely than it had been presented anywhere before, the historical background of soil studies: second, because it presented, in a compact and readable form, an account of the then most recent knowledge of the physical, chemical and biological properties of soil considered as a medium of plant growth. The book has become famous in several languages, it has passed to its seventh edition and is more than trebled in size, but it is still based upon the original foundation.

The historical introduction has been brought up to date. This introduction is an essential part of the book, the value of which is in no small measure determined by the fact that its author will always consider current work in relation to its past history and its future outlook.

The recent study of the soil from a purely scientific standpoint as distinct from its study in the interests of farming has had its proper influence upon the book, and two chapters are devoted to the "The Soil in Nature". "Soil Conditions and Plant Growth," as the title of the first edition, was tacitly understood to mean "The Soil in Agriculture." The same title applied to the present edition may fairly be interpreted as "The Soil in Nature and in Agriculture" and the book is thus enriched in matter and in outlook.

It must be admitted, in spite of the author's apparent desire that it should not be so, that this famous volume is tending to become more encyclopædic. The author is still its personal inspiration and all readers will gratefully acknowledge that Sir John Russell's world-wide travel and his increasing personal contacts with centres of soil research in many countries have enriched the book. But the very fact of the author's width of outlook upon his subject seems to necessitate more delegation in the preparation of the book and also an incipient tendency for more categorical references

and for the book to become more of a book to refer to than a book to read. The author appears to be aware of this tendency, and it is good to know that he has no wish that it shall prevail.

Its many friends will welcome the seventh edition of this book.

N. M. C.

The Study of the Soil in the Field. By G. R. CLARKE, B.Sc., M.A. [Pp. 142, with 7 figures.] (Oxford: at the Clarendon Press; London: Humphrey Milford, 1936. 5s. net.)

It is still only recently that the classification of soils and the characterisation of individual soils were attempted on the basis of chemical and physical data obtained by laboratory examination. It is now fully recognised that this laboratory examination, while very necessary, can, as Mr. Clarke says, never be more than a kind of post-mortem examination. The consideration of the "living" soil, *in situ*, with all its variations in physical, chemical and microbiological properties, is the essential basis of the classification of soils.

The first few pages of this book, including Mr. Morison's Preface, constitute a concise account of the present outlook upon field studies. There follows an account of the chief factors involved in the characteristics of the soil-site and then of the factors to be considered in studying a soil profile in a prepared pit. A careful account is given of the method of removing a portion of the profile—the monolith—for laboratory study and museum purposes.

In the chapter dealing with the actual mapping of the data gathered in field studies the author successfully faces the most difficult part of his undertaking. He gives references to certain works on "Field Sketching" and on "The Use of Maps" which will help many readers in acquiring the background needed for the full appreciation of this chapter.

The book concludes with what is essentially a survey of systems of soil studies in the field.

Mr. Clarke writes with authority on a subject in the development of which he has taken a very prominent part. In a small book of 142 pages he has gathered together a wealth of information which will be welcomed by all soil students and particularly by those who have not had the opportunity to be personally in touch with the field studies of recent years.

N. M. C.

Conservation of the Soil. By A. F. GUSTAFSON, Ph.D. [Pp. xviii + 312, with 195 figures.] (New York and London: McGraw-Hill Publishing Co., Ltd., 1937. 18s. net.)

THE author tells us that his interest in soil erosion began in boyhood days and that nearly every spring found him replacing corn that had been washed away. He has made the subject a life study and writes with the authority of a Professor of Soil Technology who has worked as an expert in the United States Soil Conservation Service.

This book is essentially written for landowners, farmers and soil students in the United States, where it is tentatively estimated that 13 million acres have been ruined and 600 million acres damaged by water and wind erosion.

The early chapters survey in some detail the losses and damage that have occurred and the influence of such facts as the distribution of rainfall and slope of land upon the effects of water and wind in removing productive

soil. The covering of productive soil in some areas by wind-blown sand is also described.

It is pointed out that under natural conditions of either forest or prairie the vegetation and the maintenance of organic matter largely prevent erosion losses. It is therefore becoming a part of farming practice in endangered areas for the organic matter content to be maintained at a high level for the purpose of binding the soil, and consideration is given in such areas to the use, as far as possible, of close-growing crops.

Cropping on the contour lines of sloping ground tends to reduce losses and the practice of strip crossing (that is, growing all the crops of a rotation in strips across a slope and on the contour line) seems to be increasing.

The various systems of terracing slopes and of constructing wind breaks are described in some detail.

Students of soil problems in countries in which the erosion menace is fortunately not so great as in America, will find this book interesting and useful although perhaps a little too detailed. There are 195 illustrations which are well worth examining.

N. M. C.

ZOOLOGY

Cold Spring Harbor Symposia on Quantitative Biology. Vol. IV. [Pp. xii + 376, with numerous figures.] (Cold Spring Harbor, L.I., N.Y.: The Biological Laboratory, 1936.)

THIS volume is devoted to problems of actuality and controversial aspects of the phenomena of nervous conduction, excitation, and neuromuscular transmission, to mention the chief subjects of its 36 articles. The succinct presentation of the various problems and the lively discussions make stimulating reading, and certainly succeed in their object of presenting the state of knowledge and speculation at the time of the meetings.

Space does not permit of a mention of all the interesting contributions, but attention may be called to a few. J. Z. Young gives an account of the giant nerve fibres and synapses found in certain invertebrates. An increase in precision of knowledge of the structure of these elements cannot fail to be of importance from the point of view of progress in knowledge of their function. The ultra-structure of nerves as revealed by X-ray and polarised light studies is dealt with in a most interesting article by F. O. Schmitt. Particularly important is the new evidence concerning the organisation and birefringence of the constituent elements of the axon and of the myelin sheath.

The problem of the function of acetylcholine and sympathin in neuromuscular transmission is considered by several contributors, including H. H. Dale; and L. Lapique develops a hypothesis to account for the new data and to co-ordinate the chemical and physical explanations of the phenomena. This hypothesis is based on the supposition that the chemical substance acts, not between nerve-ending and muscle end-plate, but as a distributor from the muscle end-plate to the muscle of the excitation which has been conveyed from the nerve-ending by physical means. A commentary on this hypothesis is added by Dale.

Especially interesting is an article by H. Hoagland on the phenomenon of "pacemakers" in the nervous system, leading to the problem of appreciation of passage of time. The potentials set up in the cerebral cortex are

discussed by several contributors, and G. H. Parker gives an account of the control of chromatophores by means of neurohumours.

G. R. DE B.

The Pests of Fruits and Hops. By A. M. MASSEE, D.Sc., F.R.E.S.
[Pp. 294, with 27 plates.] (London: Crosby, Lockwood & Son, Ltd., 1937. 15s. net.)

COMMERCIAL growers and students alike have witnessed during the last twenty years huge developments in the production of fruit. These changes have been in many directions, but perhaps nowhere so arresting as on the pest side and their control. New pests, such as certain Capsids, the Fruit Tree Red Spider and the Strawberry mite, unknown before the war, are now everyday occurrences. Power machines, tar-distillates, petroleum washes and Derris preparations are now all part of the modern fruit-grower's equipment. His book of reference was Theobald's *Insect Pests of Fruit*, out of date, largely unobtainable, but still a modern classic.

Dr. Massee of East Malling has taken a leading part in these changes and is the accepted authority on fruit pests and their control. *The Pests of Fruits and Hops* is therefore doubly welcome.

This book is frankly an attempt to lay before the fruit-grower and student a simple and brief account of some of the more important insects and allied pests that occur on top and soft fruits and on hops. Technical descriptions of insects have been omitted on purpose and the information given is designed to enable the practical man quickly to recognise the pest in the field, either from its appearance or nature of the damage done. To aid this Dr. Massee has called upon Mr. R. M. Greenslade and he has responded by producing many excellent illustrations both of pests and their damage.

The first twelve chapters deal with pests in the alphabetical order of the various fruits. Thus Chapter 1 is on Apple pests. At the beginning of each of these chapters is a list of the pests grouped under such headings as "Beetles," "Moths," "Sawflies," etc. Accompanying each entry is a statement as to the part of the plant attacked and a page reference. Asterisks indicate the most important pests. This feature is most useful. The information about each pest is then placed before the reader with such side-headings as "recognition in the field," "notes on life-cycle" and "control measures." At the end of the paragraphs concerning each pest there is a short list of references which may be consulted for additional information, the systematic or technical ones being marked with an asterisk. Chapter 13 is on beneficial and harmless insects; chapter 14 on insecticides; and chapter 15, by Mr. J. Turnbull of the Ministry of Agriculture, on spraying equipment and methods. Finally, there is a scientific index, accompanied by a popular one and an index of authors.

The subject matter of this book is characterised by its accuracy, succinctness and clarity. There are remarkably few serious omissions, the popular and scientific names used have much to recommend them and throughout one has the comfortable feeling of listening to an authority. The format is pleasing and utilitarian. So is the price. One cannot get away from the fact, however, that Dr. Massee has apparently catered for the man who already knows quite a lot about pests and fruit-growing. In other words, by carrying out the intention of producing an up-to-date work for commercial growers, the author may have been compelled to sacrifice

in some measure its palatableness to a far wider field of readers. This book deserves the length of life and demand accorded to Theobald's *Insect Pests of Fruit*.

H. F. B.

Mineral Nutrition of Farm Animals. By H. H. MITCHELL and F. J. McCLEURE. Bulletin of the National Research Council, No. 99. [Pp. 135.] (Washington, D.C. : National Research Council of the National Academy of Sciences, 1937. \$1.00.)

THIS bulletin deals in a concise but very clear manner with the whole field of the mineral nutrition of farm animals. After some account has been given of the mineral content of farm foods, the availability and utilisation of minerals in a ration, and some of the factors affecting the same, as well as the evidences of mineral malnutrition in animals, the requirements of the individual species are considered each under their own heading. A chapter at the end dealing with the practical aspects of the subject should be of considerable value to the stock feeder, and this utility is enhanced by tables in the appendix giving the percentages of the various mineral constituents in a large number of foodstuffs, and also the estimated requirements for calcium and phosphorus of the different species according to body weight and dry matter, and/or net energy requirements of food. Attention is also paid to the requirements for egg-production in fowls and for pregnancy and lactation in other classes of stock. The excellence and usefulness of the bulletin is rounded off by a very full bibliography giving some 600 references. The bulletin should be of use equally to the stock feeder and to the scientific research worker.

W. GODDEN.

Das Gefüge des Lebens. By DR. LUDWIG VON BERTALANFFY. [Pp. vi + 197, with 67 figures.] (Leipzig : B. G. Teubner, 1937. RM. 6.80, bound ; RM. 5.10 outside Germany.)

THIS is a remarkably compact, comprehensive and up-to-date account of the main facts of biology looked at from the organismal point of view. The author, formerly of Vienna and now at the University of Chicago, is, of course, well known as one of the leading exponents of this integrative view of the living thing, which avoids the pitfalls of mechanism and of vitalism, and leads to a more adequate conception of the living organism as a unitary dynamic process. In his *Theoretische Biologie* (Vol. I, 1932), which was reviewed in this journal (Vol. XXVIII, p. 363), the organismal theory is fully discussed and justified ; the present volume contains a shorter and more concrete exposition of it. The book covers the whole field of biology, from colloid chemistry to the study of intelligent behaviour, and the value of the organismal approach is emphasised throughout. The physiology of development and the theory of heredity and evolution are dealt with only in outline, as these form the subjects of other books, by Dürken, Lehmann and Heese, in the same series.

The book can be heartily recommended, and should be read by all biologists who wish to keep in touch with the theoretical developments in their science. The importance of regarding the organism as a functional and dynamic whole appears to be establishing itself in Continental biology, but it penetrates slowly in this country. For this reason it is to be hoped that someone will undertake an English translation.

There is little to say in the way of criticism ; we found the treatment of the gene theory and the problem of instinct particularly good and illuminating ; there is a useful bibliography and glossary, and the illustrations are well chosen. Whether the organismal theory, in the form given to it by Bertalanffy, goes sufficiently far to include all vital manifestations, especially those we are accustomed to separate off as psychological, is a matter for discussion, but it certainly represents a considerable advance on the older views.

E. S. RUSSELL.

The Intelligence of Animals. By G. C. GRINDLEY, M.A., B.Sc. Methuen's Monographs on Philosophy and Psychology. [Pp. viii + 70, with 1 figure.] (London : Methuen & Co., Ltd., 1937. 2s. 6d. net.)

MR. GRINDLEY, who is Lecturer in Experimental Psychology at Cambridge, has been given a very difficult task. It is no easy matter to cover such an extensive field in such small compass. Within the limits of space and his own restriction of the field to the results of laboratory work he has made a good job of it. One is inclined to suggest that too much emphasis is placed on the importance of exact experimental results, and too little upon the biological background of behaviour. Also the short bibliography of suggestions for further reading seems unnecessarily restricted in scope.

The subject matter is dealt with under the following heads—The Evolution of Animal Intelligence, The Main Forms of Learning (habituation, conditioned responses, and trial and error learning), Reasoning. In the first section, in discussing instinct and intelligence, Grindley seems to us to underestimate the part played by instinct in the higher mammals. It is true that their instinctive behaviour can be greatly modified through experience, but no one who has watched a bitch produce and tend her first litter would subscribe to the statement on p. 21 that the exact means by which instinctive ends are attained in the higher mammals are determined through individual experience. This is only partially true.

E. S. RUSSELL.

MEDICINE

A Text-Book of Physiology. By H. E. ROAF, M.D., D.Sc., M.R.C.S., L.R.C.P. Second Edition. [Pp. viii + 679, with 338 figures.] (London : Edward Arnold & Co., 1936. 21s. net.)

In prefacing this new edition of his *Text-Book of Physiology* the author explains that his aim is to present "a reasonable account of physiology with a logical presentation of material," the implication being that if the fundamental principles of mechanics, physics and chemistry involved in physiological processes are once grasped by the student, the subject will be shorn of many of its difficulties. To achieve this purpose the book is divided into four parts, of which the first two are designed to deal with the fundamental principles involved, and the last two with what one might call more purely biological phenomena.

As the mechanical principles are assumed to be more familiar to the student than the physical and chemical ones, the former are introduced first, so that Part I is headed Mechanical Aspects, and Part II Chemical Aspects. This half of the book is not, however, confined to discussions of mechanics, physics and chemistry, but as each principle is introduced the

physiological mechanisms based on these are also described, so that Part I contains the physiology of the skeletal system, a description of respiratory movements, events of the cardiac cycle and significance of heart sounds, concluding with a very condensed account of histological methods and the general structure of the tissues. Part II, continuing in a similar way, includes the chemical aspects of respiration, the physiology of digestion, absorption and metabolism, and urinary analysis.

As distinct from the fundamental mechanical and chemical processes, the biological co-ordinating mechanisms are described in Part III, which is chiefly occupied with the nervous system (including the special senses), and the endocrine glands. The regulation of the circulation and respiration is also postponed to this part. The fourth part of the book deals with the maintenance of the individual and reproduction, and includes nutrition, reproduction and heredity.

With the ever-greater complexity of modern physiology, where it is becoming increasingly difficult to appreciate any one system without knowing something of the others, the arrangement of material in a text-book presents many problems. But it is difficult to feel that Professor Roaf's arrangement presents any concrete advantages over the more orthodox ones. One sees how very arbitrary is the division of physiological processes into chemical aspects, mechanical aspects and integrating mechanisms, and such a division has the disadvantage of making the subject rather disconnected, as, for example, the account of respiration which is described in Chapters 4, 19, 35 and 41. One also feels that insufficient space has sometimes been allotted to important subjects, *e.g.* the whole question of hyperthyroidism is dismissed in ten lines.

The book is, however, very readable, and profusely illustrated, and for the student making his first acquaintance with physiology it should be useful in helping him to gain that background of knowledge of the working of the body so essential to a medical career.

D. H. S.

PHILOSOPHY

The Philosophy of Religion versus the Philosophy of Science.

By ALBERT EAGLE. [Pp. 352.] (Printed for private circulation, obtainable through all booksellers from Simpkin Marshall, Ltd. 5s.)

THE thesis maintained in this book is that we must think in terms of three categories—space, time and substance. It is taken as axiomatic that space has only three dimensions, since more are unthinkable. Space and time being in themselves void, all properties of nature must be properties of substance, and it is proposed to explain the phenomena of physics, biology and psychology in terms of four kinds of substance, each occupying space and enduring through time. These are called respectively the "inner-ego," the "mental substance," the "non-material body," and the "material body," and are regarded as being patterns on the Being of God which, in the ultimate philosophical analysis, is the only substance in existence. The book is partly an attempt to show that this hypothesis is the only one that fits known facts, and partly a tirade against those aspects of prevailing scientific views (particularly the theory of relativity) which conflict with it.

We find the constructive part of the book unconvincing and the destructive part ineffective. The author's passion distorts whatever power of critical

judgment he might possess, and makes havoc alike of reason, grammar and diction. The so-called successes of relativity are described as "largely accidents," and the whole relativity theory is regarded as merely a mathematical trick for relating physical measurements with one another, devoid of "explanation" of what occurs. It is not easy to understand why the author, with his view of what constitutes "explanation," does not at once solve all scientific problems merely by ascribing whatever happens to the Will of God; it would be so much simpler than invoking a multiplicity of patterns to explain isolated phenomena. Indeed, he almost reaches this ideal in biology. "How luminously explicable all biological phenomena are," he writes, "if we will only recognise an invisible, non-material world in which unseen intelligences are working to produce definite ends which *they* know all about, but of which we are ignorant." In an age in which the prevailing vice is a too easy acceptance of nonsense backed by authority, Mr. Eagle's independence is not unrefreshing, but when absolute values are considered it is doubtful whether the blind fury of his dogmatism, despite the arrogant protestation of humility which accompanies it, is not worse than the bovine docility against which he thunders.

H. D.

Science and Reality. By J. M. Lowson, M.A., B.Sc., F.L.S. [Pp. viii + 142, with 4 figures.] (London: C. A. Watts & Co., Ltd., 1936. 5s. net.)

In this book an attempt is made to find a *real* explanation of the universe. Science is restricted by its methods to the investigation of a *phenomenal* world, and reality is probably attainable only by cautious inference from the most reliable observations and generalisations of science. The reality that lies *immediately* behind phenomena, however, need not be the ultimate existence, but its nature might provide philosophers with more assured premisses on which to base their speculations about ultimate existence. The conclusion reached is that "the real existence *immediately* behind phenomena, which may simply be called the ether, is to be conceived as Cosmic Energy directed and controlled by Cosmic Mind," and various possible philosophical speculations about ultimate existence, compatible with this conclusion, are mentioned. As is usual with books of this type (e.g. Mr. Eagle's book reviewed above), the "explanation" arrived at is virtually a change of name. Thus, "*Here we have the fundamental explanation and the innermost mechanism of that responsiveness to the action of stimuli* manifested not only by living organisms, but also by inorganic substances. *The physical and chemical forces acting between atoms and molecules must also be thought of as regulated by cosmic mind*" (author's italics). The principle of relativity is rejected and an alternative suggested, and the author puts forward a theory of terrestrial magnetism which not only rests on a very speculative basis, but also is presented with such absence of detail that criticism is scarcely called for. If the author is serious he should put it in a form in which it can receive serious consideration. The possible variety of books of this kind seems infinite, since speculation about reality is unbridled. The author pays lip service to the need for restraint when he states that "the philosopher must seek for reliable premisses in the *latest* (reviewer's italics) results, and generalisations, and inferences of all the sciences," but since he assumes, among other things, a minute undiscovered difference of charge between positive and

negative electrons before arriving at the reality *immediately* behind phe the limitation is not likely to become irksome.

H. D.

A Creed for Sceptics. By C. A. STRONG, LL.D. [Pp. ix + 98.] (London : Macmillan & Co., Ltd., 1936. 6s. net.)

THIS book is extremely difficult to appraise. It contains five chapters—one of which is in French and another written almost entirely by Voltaire—and two original poems. The author is a sceptic, *i.e.* a “disbeliever in traditional religion,” but not a philosophic sceptic, for his book is described as “a defence of knowledge against philosophic doubt.” He appears, however, to maintain neither attitude consistently, for although the last chapter asserts that the universe has no consciousness, the first loses its force if the frequent teleological arguments are not taken literally; and in spite of the claim in the Preface “that things are real and that perception is a knowing of them,” we reach at the end the conclusion that “the clearest reasoner must be, in the final review, a sceptic, and admit, with Socrates, that he does not definitively *know*.” The difficulties aroused by these passages are typical of many that meet the careful reader. The scientifically minded will want to know whether the author’s philosophy is based on experience or not. The suggestion of p. 92 is that it is, for he rejects the unity of the universe by “confining ourselves to what experience shows,” yet p. 28 tells us that the existence of things is quite independent of our experience of them. Again, what can the simple-minded make of such a sentence as this: “It was the shadowy, evanescent, unreal nature of the datum that disposed me to think of it as an essence”? Whenever we have believed ourselves to have grasped the author’s meaning at last, another passage has occurred to prove us wrong. After reading the book we can agree heartily with him that “the only right intellectual attitude toward the universe is, in my opinion, that of science,” but we cannot explain why he has not adopted it.

H. D.

MISCELLANEOUS

Back in the Stone Age. By CHARLES CHEWINGS, Ph.D., F.G.S., F.R.G.S., A.M.I.M.E. [Pp. xxii + 162, with 23 plates.] (Sydney : Angus & Robertson, Ltd. ; London : The Australian Book Co., 1936. 7s. 6d.)

THE aborigines of Central Australia have interested the scientific for many years, especially since the classic work of Spencer and Gillen. Their extremely simple material culture—they may truly be considered to live still in the Stone Age—their elaborate ceremonial, their complex social organisation have all contributed to this interest. The late Prof. Sollas, in his well-known work *Ancient Hunters*, compared them with Mousterian Man. Recently the whole question of their survival has become a matter of public discussion. The Aranda people, as the present author spells their tribal name, probably owe their survival to their very remote geographical position. The advance of modern civilisation and the inevitable culture contacts put these people in considerable peril. The author of the present book, who has had a lifetime experience of these remote people, gives a clear account of their ordinary manner of life, their methods of gaining food, their social organisation and their general outlook on life. He also gives a good deal of information

about their relations to the Whites. The book is simply written and is intended to supply information which may be of value to the ordinary man who may wish to form an opinion on the vexed question of the protection of aborigines. The anthropologist will probably not find very much that is new, but the man who finds anthropological works either too technical or even too revolting will find in this short book a great deal of accurate information. The illustrations are excellent and well chosen and a useful map is provided as an end-paper.

L. H. D. B.

Twins : A Study of Heredity and Environment. By H. H. NEWMAN, F. N. FREEMAN and K. J. HOLZINGER. [Pp. xvi + 369, with 39 plates and 33 figures.] (U.S.A.: University of Chicago Press; Great Britain and Ireland: Cambridge University Press, 1937. 18s. net.)

THIS large book constitutes an ample and detailed report of researches carried out over a period of ten years, in which "a psychologist, a statistician and a specialist in the biology of twins" co-operated. It is, as would be expected, much the most thorough study of the kind that has yet appeared. In recent years the view has been often put forward, with a confidence perhaps proportional to the inexperience of the writer, that twin studies would prove of revolutionary importance in elucidating such important questions as the measurement of the influence of hereditary and environmental factors on desirable human characteristics. The results of the studies here reported, and the wisely temperate tone of the authors, should go far to dispel this illusion; it is not that the results attained lack permanent and substantial scientific value; it is rather that their interpretation is hampered by just the same difficulties, some technically statistical, and some more properly experimental, which are encountered in other human studies.

In the first investigation, dealing with a comparison between fifty monozygotic and fifty dizygotic pairs, a point of great interest emerges in the average differences within such pairs of different traits. Differences between monozygotic twins must be ascribed in part to errors in measurement, and in part to environmental differences of an accidental character. Dizygotic twins differ, in addition, in hereditary factors, to about half the extent, in fact, that unrelated persons would differ in a well-mixed population. The ratio between the average differences constitutes, therefore, a simple and direct measure of the importance of heredity compared with such accidental environmental factors as may affect persons of the same social class. The order in which different traits stand in respect of this ratio is, therefore, of very general interest.

Of the traits listed (Table X, p. 72) the highest ratio (3.78) is given by the total count of the finger-print ridges. Next come stature 2.59, and weight 2.44. These are the three traits for which heredity has the highest importance. More moderate values are shown by head-length 2.14, Otis intelligence quotient 2.07, Stanford educational age 1.81, Cephalic index 1.75, and Binet intelligence quotient 1.68. The three lowest ratios are given by head width 1.50, total motor score 1.50, and Woodworth-Mathews tests 1.28.

Psychologists and anthropologists will note with interest that current methods of measuring intelligence are at least as greatly influenced by genetic differences as are some of the classical measurements of ethnography.

The list suggests, indeed, that height and weight, together with measurements of intelligence, have not been sufficiently appreciated as indications of racial affinity, and that measurements of the head may have been over-rated. The low ratios for the temperamental tests are reasonably explicable from their low reliability on repeated testing of the same individual.

The order assigned to the traits is confirmed, for those not greatly dependent upon age, by the differences between the correlations, measured on the *z* scale, shown in Table 26 (p. 98):

Finger ridges	1.362
Otis I.Q.	0.875
Cephalic index	0.819
Binet I.Q.	0.770

It would be of interest to extend the comparison, by making allowance for age, to the remaining traits; since, in this case, we are dealing with comparisons between different sets of twins, and therefore differences in home environment, so far as they are effective, are here present, in addition to the accidental environmental differences between children reared in the same home.

A large part of the book (pp. 131-334) is devoted to detailed case records of twins separated early in life, and an attempt is made to correlate twin differences with estimated differences in the home environments. As would be expected, no significant correlations appear with the physical measurements, the majority being negative, with the exception of weight, which is found to be associated with the home rating of physical well-being and health. Intelligence tests, however, are found to be strongly associated with educational opportunity. Table 93 (p. 340) also gives three of these tests out of five as significantly associated with social differences, but it appears that the table is giving total correlations, and, since educational and social advantage are said to be themselves correlated positively (Table 92 gives the value 0.260), it appears that the social factor alone is without significant effect on apparent intelligence. The authors appear to overlook this point, for they say, p. 341, "There thus appears an undeniable tendency for wide social differences to be associated with differences in intelligence, whether measured by verbal or non-verbal tests." Such association as may exist, however, appears to be insufficient to be judged significant on the basis of the nineteen pairs of twins here studied, and even the non-significant residual effect may well be ascribed to the inevitable inaccuracy of the rating of the educational opportunities offered by different homes, since, if a variable be inaccurately measured, its influence will be only partially removed by the technique of partial correlation.

The book is well supplied with tabular data, which deserve careful study. The reviewer has not, however, found any statement to the effect that the complete data of the two investigations have been here put on record. If so, it must have been scattered in a large number of tables of secondary data.

R. A. F.

The Design of Experiments. By R. A. FISHER, Sc.D., F.R.S. Second edition. [Pp. xii + 260, with 5 figures.] (Edinburgh and London: Oliver & Boyd, 1937. 12s. 6d. net.)

It was suggested in the review in these pages of the first edition of Prof. Fisher's new book that its importance would lie in the foundations it laid

of a new branch of science, that of "experimentation." That is still the reviewer's opinion, and the early appearance of a new edition is evidence that the seed has not fallen on stony ground. The book is substantially unaltered. There are a number of numerical corrections, but apart from this the changes are additive. Details are given in Section 35 of completely orthogonalised 8×8 and 9×9 Græco-Latin squares, and a new section which follows describes an exceptional design which was found of utility in a cotton-mill experiment in order to trace a winding defect. Examples have been added at the end of Chapter VII which illustrate some of the newly developed combinatorial arrangements, which, the author states in a supplementary preface, are attracting considerable interest. The attractiveness of the dust cover is enhanced by the adding of a seven-colour diagram illustrating a Latin square design.

J. W.

The Official Year-Book of the Scientific and Learned Societies of Great Britain and Ireland. Fifty-fourth annual issue. [Pp. viii + 172.] (London: Charles Griffin & Co., 1937. 10s. net.)

THIS useful and well-produced book gives in considerable detail information of the activities of some 600-700 societies: officers, membership conditions, meetings and publications (including where possible a detailed list of papers and reports issued during the session 1936-37). Its scope may be judged by the following selection at random from the index: Child Study Society, Forest Products Research Laboratory, Egypt Exploration Society, Staffordshire Iron and Steel Institute. A great quantity of material has been brought together, concisely arranged and—an important point—well indexed; the result is a valuable reference book for the scientific world and for those who have dealings with it.

Its pages are a testimony to the vitality of scientific thought in this country, as manifested not only by august and world-famous institutions, but by those innumerable provincial and professional groups of enthusiasts whose unspectacular labours in collecting, recording and discussing observed facts are of the very stuff of scientific enquiry.

P. J. E.

BOOKS RECEIVED

(Publishers are requested to notify prices.)

- Modern Higher Algebra.** By A. Adrian Albert, Associate Professor of Mathematics, The University of Chicago. U.S.A.: University of Chicago Press; Great Britain and Ireland: Cambridge University Press, 1937. (Pp. xiv + 319.) 18s. net.
- Trigonometry.** Part III: Advanced Trigonometry. Part IV: Spherical Trigonometry. By T. M. MacRobert, M.A., D.Sc., Professor of Mathematics, and William Arthur, M.A., Lecturer in Mathematics, in the University of Glasgow. London: Methuen & Co., Ltd., 1938. Part III (pp. 345-478), 4s. 6d.; Part IV (pp. 479-541, with 20 figures), 3s.
- Bessel Functions.** Part I: Functions of Orders Zero and Unity. British Association Mathematical Tables, Vol. VI. Prepared by the Committee for the Calculation of Mathematical Tables. Published for the British Association at the University Press, Cambridge, 1937. (Pp. xx + 288.) 40s. net.
- Segmental Functions.** Text and Tables. By C. K. Smoley. Scranton, Pa.: C. K. Smoley & Sons, 1937. (Pp. xlv + 184, with 11 figures.) \$5.00 net.
- Frequency Curves and Correlation.** By W. Palin Elderton, C.B.E., F.I.A., F.F.A. Third edition. Cambridge: at the University Press, 1938. (Pp. xii + 271, with numerous tables.) 12s. 6d. net.
- A Text-Book of Convergence.** By W. L. Ferrar, M.A., F.R.S.E., Fellow and Tutor of Hertford College, Oxford. Oxford: at the Clarendon Press; London: Humphrey Milford, 1938. (Pp. viii + 192.) 10s. 6d. net.
- Contributions to the Calculus of Variations 1933-1937.** Theses submitted to the Department of Mathematics of the University of Chicago. U.S.A.: University of Chicago Press; Great Britain and Ireland: Cambridge University Press, 1937. (Pp. viii + 566.) 13s. 6d. net.
- Introduction to Mathematical Probability.** By J. V. Uspensky, Professor of Mathematics, Stanford University. New York and London: McGraw-Hill Publishing Co., Ltd., 1937. (Pp. x + 411, with 20 figures and 9 tables.) 30s. net.
- Scripta Mathematica Forum Lectures.** Addresses by Cassius Jackson Keyser, David Eugene Smith, Edward Kasner, Walter Rautenstrauch. The Scripta Mathematica Library No. 3. New York: Yeshiva College, 1937. (Pp. iv + 94, with 8 figures.) \$1.00.
- Motion and Time Study.** By Ralph M. Barnes, M.E., Ph.D., Professor of Industrial Engineering, College of Engineering, University of Iowa.

- New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd., 1937. (Pp. x + 285, with 123 figures and 41 tables.) 18s. 6d. net.
- Glossary of Physics.** Compiled and edited by Le Roy D. Weld, Ph.D., Professor of Physics in Coe College. New York and London: McGraw-Hill Publishing Co., Ltd., 1937. (Pp. x + 255.) 15s. net.
- Hevelius, Flamsteed and Halley. Three Contemporary Astronomers and Their Mutual Relations.** By Eugene Fairfield MacPike, F.R.A.S. London: Taylor & Francis, Ltd., 1937. (Pp. x + 140, with 5 plates.) 12s. 6d. net.
- The Observational Approach to Cosmology.** By Edwin Hubble, of the Mount Wilson Observatory, Carnegie Institution of Washington. Oxford: at the Clarendon Press; London: Humphrey Milford, 1937. (Pp. x + 68, with 7 plates, 3 figures and 2 tables.) 6s. net.
- The Universe Surveyed. Physics, Chemistry, Astronomy, Geology.** By Harold Richards. With a Preface by Kirtley F. Mather, Chairman of the Department of Geology, Harvard University. London: Kegan Paul, Trench, Trubner & Co., Ltd., 1938. (Pp. xviii + 722, with 94 figures.) 12s. 6d. net.
- The Fundamental Principles of Quantum Mechanics. With Elementary Applications.** By Edwin C. Kemble, Professor of Physics, Harvard University. International Series in Physics. New York and London: McGraw-Hill Publishing Co., Ltd., 1937. (Pp. xviii + 611, with 27 figures.) 36s. net.
- Thermodynamics.** By Enrico Fermi, Professor of Physics, the University of Rome. London and Glasgow: Blackie & Son, Ltd., 1938. (Pp. x + 160, with 22 figures.) 12s. 6d. net.
- The Flow of Homogeneous Fluids Through Porous Media.** By M. Muskat, Ph.D., Chief of Physics Division, Gulf Research and Development Company. With an Introductory Chapter by R. D. Wyckoff, B.S. in E.E. New York and London: McGraw-Hill Publishing Co., Ltd., 1937. (Pp. xx + 763, with 279 figures and 19 tables.) 45s. net.
- Light. Principles and Experiments.** By George S. Monk, Assistant Professor of Physics, University of Chicago. New York and London: McGraw-Hill Publishing Co., Ltd., 1937. (Pp. xii + 477, with 269 figures.) 30s. net.
- The Science of Seeing.** By Matthew Luckiesh, D.Sc., D.E., Director, Lighting Research Laboratory, General Electric Company, Nela Park, Cleveland, and Frank K. Moss, E.E., Physicist, Lighting Research Laboratory. New York: D. van Nostrand Co., Inc.; London: Macmillan & Co., Ltd., 1937. (Pp. x + 548, with 143 figures, 84 tables and chart in pocket.) 25s. net.
- Introduction to Physiological Optics.** By James P. C. Southall, Professor of Physics in Columbia University. London: Oxford University Press, 1937. (Pp. x + 426, with 135 figures, including 3 plates.) 21s. net.
- The Lightning Discharge.** The Halley Lecture delivered on 28 May, 1937, by Professor B. F. J. Schonland, O.B.E., M.A., Ph.D., Director of the Bernard Price Institute of Geophysics, The University of the Witwaters-

rand, Johannesburg. Oxford: at the Clarendon Press; London: Humphrey Milford, 1938. (Pp. 19, with 8 figures, including 2 plates.) 2s. net.

The Battery Book. A Practical Manual. By Harold H. U. Cross, Electrical Engineer. With a Foreword by James Y. Fletcher, A.M.I.E.E. London: The Technical Press, Ltd., 1937. (Pp. xii + 196, with 92 figures.) 5s. net.

Alternating Current Electrical Engineering. By Philip Kemp, M.Sc.Tech., M.I.E.E., A.I.Mech.E., Mem.A.I.E.E., Head of the School of Engineering at the Polytechnic, Regent Street, London. Fifth edition. London: Macmillan & Co., Ltd., 1937. (Pp. x + 611, with 421 figures and 1 folding plate.) 15s.

Aero and Auto Engine Facts and Data. By H. R. Langman. London: The Technical Press, Ltd., 1937. (Pp. x + 85, with 14 figures.) 2s. 6d. net.

Materials and Structures. A Text-Book for Engineering Students. Vol. II: The Theory and Design of Structures. By E. H. Salmon, D.Sc. (Eng.), M.Inst.C.E. London, New York, Toronto: Longmans, Green & Co., 1938. (Pp. viii + 796, with 516 figures.) 32s. net.

Conveying Machinery. By William H. Atherton, M.Sc., Member of Council of the Whitworth Society. London: The Technical Press, Ltd., 1937. (Pp. viii + 188, with 17 plates, 121 figures and 10 tables.) 21s. net.

Hackh's Chemical Dictionary. By Ingo W. D. Hackh, A.M., F.A.I.C., F.R.S.A., Professor of Chemistry, College of Physicians and Surgeons, A School of Dentistry, of San Francisco, California. With the collaboration of Julius Grant, M.Sc., Ph.D., F.I.C. Second edition. Philadelphia: P. Blakiston's Son & Co., Inc.; London: J. & A. Churchill, Ltd., 1938. (Pp. x + 1020, with numerous illustrations.) 48s. net.

Gmelins Handbuch der anorganischen Chemie. 8.Auflage. Herausgegeben von der Deutschen Chemischen Gesellschaft. System-Nummer 22: Kalium, Lieferung 4. Berlin: Verlag Chemie, G.m.b.H., 1937. (Pp. 805-932, with 6 figures.) Reduced price abroad RM.15.-.

Gmelins Handbuch der anorganischen Chemie. 8.Auflage. Herausgegeben von der Deutschen Chemischen Gesellschaft. System-Nummer 24: Rubidium. Berlin: Verlag Chemie, G.m.b.H., 1937. (Pp. xviii + x + 250, with 7 figures.) Reduced price abroad RM.31.50.

Outlines of Theoretical Chemistry. By Frederick H. Getman, Ph.D., formerly Associate Professor of Chemistry in Bryn Mawr College. Sixth edition by Farrington Daniels, Professor of Chemistry in the University of Wisconsin. New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd., 1937. (Pp. x + 662, with 170 figures and 117 tables.) 18s. 6d. net.

Catalysis. From the Standpoint of Chemical Kinetics. By Georg-Maria Schwab, Professor-Extraordinary of Chemistry at the University of Munich. Translated from the first German edition, with additions from the recent literature by the author, by Hugh S. Taylor, David B. Jones Professor of Chemistry, Princeton University, and R. Spence, Lecturer in Physical Chemistry, Leeds University. New York: D. van Nostrand Co., Inc.; London: Macmillan & Co., Ltd., 1937. (Pp. xii + 357, with 39 figures and 38 tables.) 18s. net.

- Physikalische Methoden im chemischen Laboratorium.** Sammelband mit 13 Arbeiten aus der "Angewandten Chemie" 1936 und 1937. Berlin: Verlag Chemie, G.m.b.H., 1937. (Pp. viii + 267, with 89 figures and 38 tables.) Reduced price abroad RM.2.70.
- The German Patent Position of Arc Welding Electrodes. Coverings, Welding Rods and Fluxes.** By Werner H. Simon, Dipl. Ing., A.M.Inst.W. (Pp. 80.) Obtainable from the Institute of Welding, 28, Victoria Street, London, S.W.1. £2 10s. net.
- Modern Theories of Organic Chemistry.** By H. B. Watson, D.Sc., F.I.C., Head of the Department of Chemistry at the City of Cardiff Technical College. Oxford: at the Clarendon Press; London: Humphrey Milford, 1937. (Pp. viii + 218, with 21 figures.) 15s. net.
- Laboratory Technique in Organic Chemistry.** By Avery Adrian Morton, Associate Professor of Organic Chemistry, Massachusetts Institute of Technology. International Chemical Series. New York and London: McGraw-Hill Publishing Co., Ltd., 1938. (Pp. x + 261, with 122 figures and 65 tables.) 15s. net.
- The Chemistry of Petroleum Derivatives. Vol. II.** By Carleton Ellis, Industrial Research Chemist. New York: Reinhold Publishing Corporation; London: Chapman & Hall, Ltd., 1937. (Pp. 1464, with 354 figures.) £5 net.
- Polymerization and its Applications in the Fields of Rubber, Synthetic Resins, and Petroleum.** By Robert E. Burk, Professor of Chemistry, Western Reserve University, Howard E. Thompson, Research Chemist, the Harshaw Chemical Company, Archie J. Weith, Associate Director of Research, the Bakelite Corporation, and Ira Williams, Research Chemist, E.I. du Pont de Nemours & Co. American Chemical Society Monograph Series. New York: Reinhold Publishing Corporation; London: Chapman & Hall, Ltd., 1937. (Pp. 312, with 6 figures and 134 tables.) 37s. 6d. net.
- Modern Rubber Chemistry.** By Harry Barron, Ph.D., B.Sc., A.I.C., A.I.R.I., Industrial Consultant. London: Hutchinson's Scientific and Technical Publications, 1937. (Pp. 342, with 70 figures and 47 tables.) 18s. net.
- Synthetic Resins and Allied Plastics.** Edited by R. S. Morrell, M.A., Sc.D., Ph.D., F.I.C. In collaboration with T. Hedley Barry, F.I.C., R. P. L. Britton, and H. M. Langton, M.A., B.Sc. London: Oxford University Press, 1937. (Pp. xii + 417, with 41 figures.) 21s. net.
- Colorimetric Methods of Analysis. Including Some Turbidimetric and Nephelometric Methods. Vol. II: Organic and Biological.** By Foster Dee Snell, Ph.D., and Cornelia T. Snell, Ph.D. New York: D. van Nostrand Co., Inc.; London: Chapman & Hall, Ltd., 1937. (Pp. xxiv + 815, with 49 figures and 60 tables.) 45s. net.
- Analytical Chemistry.** Based on the German text of F. P. Treadwell, late Professor of Analytical Chemistry at the Polytechnic Institute of Zürich. Translated and revised by William T. Hall, S.B., Associate Professor of Analytical Chemistry, Massachusetts Institute of Technology. Vol. I: *Qualitative Analysis*. Ninth English edition. New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd., 1937. (Pp. x + 630, with 18 figures and 22 tables.) 22s. 6d. net.

- Clowes and Coleman's Quantitative Chemical Analysis.** An Intermediate Text-Book. Edited and revised by D. Stockdale, M.A., Ph.D., A.I.C., Fellow of King's College and University Lecturer in Chemistry, Cambridge, and J. Dexter, M.A., B.Sc., A.I.C., of the Staff of the War Department Chemist, Royal Arsenal, Woolwich. Fourteenth edition. London: J. & A. Churchill, Ltd., 1938. (Pp. xiv + 613, with 130 figures.) 18s. net.
- Chemical Analysis of Metals and Alloys.** By Edwin Gregory, Ph.D., M.Sc., A.Met., F.I.C., Mappin Medallist, Lecturer in Metallurgy, University of Sheffield, and Walter W. Stevenson, A.Met., A.I.C., Chief Chemist, Central Research Laboratories, The United Steel Companies, Ltd. With a Foreword by Thomas Swinden, D.Met. London and Glasgow: Blackie & Son, Ltd., 1937. (Pp. xvi + 375, with 51 figures.) 15s. net.
- Qualitative Inorganic Analysis.** By A. J. Berry, M.A., Fellow of Downing College and University Lecturer in Chemistry. Cambridge: at the University Press, 1938. (Pp. viii + 147.) 6s. net.
- Notes on Qualitative Organic Analysis.** By F. R. Storrie, Ph.D., A.I.C., Department of Organic Chemistry, University of Glasgow. Dent's Modern Science Series. London: J. M. Dent & Sons, Ltd., 1938. (Pp. x + 68.) 2s. 3d.
- Calculations in Quantitative Chemical Analysis.** By John A. Wilkinson, Ph.D., Professor of Analytical and Inorganic Chemistry at Iowa State College. Second edition. International Chemical Series. New York and London: McGraw-Hill Publishing Co., Ltd., 1938. (Pp. x + 154.) 10s. 6d. net.
- The Chemical Elements Interpreted.** By R. P. Byers, M.A. Boston, Mass.: Superuniversity Publications, 1937. (Pp. 26.) \$1.00.
- Chemistry (with some Geology).** By J. A. Lauwerys, B.Sc., Lecturer and Tutor in Methods of Science, Institute of Education, London, and J. Ellison, M.Sc., Senior Science Master, Trinity County School, N. 22. New General Science Series. London: University of London Press, Ltd., 1938. (Pp. xii + 356, with 146 figures.) Complete, 4s. 6d.; Part I, 3s. 3d.
- The Principles and Practice of Lubrication.** A Manual for Petroleum Technologists, Students, Engineers, Oil Salesmen, etc. By Alfred W. Nash, M.Sc., M.I.Mech.E., F.C.S., F.Inst.Fuel, Professor of Petroleum Technology, University of Birmingham, and A. R. Bowen, D.Sc., Ph.D., F.I.C., Principal, County Technical College, Newark. Second edition. London: Chapman & Hall, Ltd., 1937. (Pp. xii + 345, with 96 figures, including 26 plates and 2 folding plates, and 33 tables.) 18s. net.
- Outlines of Historical Geology.** By Charles Schuchert, Professor Emeritus of Paleontology in Yale University, and Carl O. Dunbar, Professor of Paleontology and Stratigraphy in Yale University. Third edition. New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd., 1937. (Pp. vi + 241, with frontispiece and 151 figures.) 12s. 6d. net.
- Outline of Historical Geology.** By A. K. Wells, D.Sc. London: George Allen & Unwin, Ltd., 1938. (Pp. xiv + 266, with 2 plates and 99 figures.) 12s. 6d. net.

- Our Wandering Continents.** An Hypothesis of Continental Drifting. By Alex. L. Du Toit, D.Sc., F.G.S. Edinburgh and London: Oliver & Boyd, 1937. (Pp. xiv + 366, with 48 figures.) 18s. net.
- Economic Geology.** By H. Ries, A.M., Ph.D., Professor of Geology at Cornell University. Seventh edition. New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd., 1937. (Pp. viii + 720, with 63 plates and 267 figures.) 25s. net.
- Ground Water.** By C. F. Tolman, Professor of Economic Geology, Leland Stanford Junior University. New York and London: McGraw-Hill Publishing Co., Ltd., 1937. (Pp. xviii + 593, with 189 figures.) 36s. net.
- Introduction to Plant Pathology.** By Frederick Deforest Heald, M.S., Ph.D., Head of the Department of Plant Pathology and Plant Pathologist of the Agricultural Experiment Station, The State College of Washington. McGraw-Hill Publications in the Agricultural Sciences. New York and London: McGraw-Hill Publishing Co., Ltd., 1937. (Pp. xii + 579, with 200 figures.) 24s. net.
- Vergleichende Morphologie der höheren Pflanzen. Band I: Vegetationsorgane, 1. Teil, 3. Lieferung.** Von Dr. Wilhelm Troll, o. Professor der Botanik an der Martin-Luther-Universität Halle-Wittenberg. Berlin: Gebrüder Borntraeger, 1937. (Pp. 509-955, with 368 figures.) R.M.39.50.
- General Plant Physiology.** By E. C. Barton Wright, M.Sc., Biochemist to the Research Association of British Flour Millers. With a Foreword by Sir F. Gowland Hopkins, O.M. London: Williams & Norgate, Ltd., 1937. (Pp. 539, with 44 figures.) 15s. net.
- An Introduction to Economic Botany.** By James Gillespie, B.Sc., Lecturer in Plant Physiology and Mycology, Reading University. The New People's Library, Vol. III. London: Victor Gollancz, Ltd., 1937. (Pp. 96, with 7 figures.) 1s. 6d., cloth; 1s., paper covers.
- The Structure and Development of the Fungi.** By H. C. I. Gwynne-Vaughan, G.B.E., LL.D., D.Sc., F.L.S., Professor of Botany in the University of London, and B. Barnes, D.Sc., Ph.D., F.L.S., Head of the Department of Biology, Chelsea Polytechnic, London. Second edition. Cambridge: at the University Press, 1937. (Pp. xvi + 449, with frontispiece and 309 figures.) 18s. net.
- A.B.C. of Agrobiology.** By O. W. Willcox, Ph.D., Consulting Agrobiologist. London: George Allen & Unwin, Ltd., 1938. (Pp. 323, with 22 figures.) 12s. 6d. net.
- How to Make Forestry Pay.** By Richard Coke, Vice-President, The Royal English Forestry Society. Cambridge: W. Heffer & Sons, Ltd., 1938. (Pp. 24.) 1s. net.
- Mother Earth.** Being Letters on Soil addressed to Professor R. G. Stapledon, C.B.E., M.A., Director of the Welsh Plant Breeding Station. By Gilbert Wooding Robinson, Sc.D., Professor of Agricultural Chemistry, University College of N. Wales, Bangor. London: Thomas Murby & Co., 1937. (Pp. viii + 202, with 1 plate, 6 figures and 2 maps.) 5s. 6d. net.

- A History of Agricultural Experimentation and Research in the United States 1607-1925.** Including a History of the United States Department of Agriculture. By Alfred Charles True, late Specialist in States Relations Work, United States Department of Agriculture. Miscellaneous Publication No. 251. Washington: U.S. Government Printing Office, 1937. (Pp. vi + 321, with frontispiece, 11 figures and 5 tables.) 25 cents (paper).
- The Axiomatic Method in Biology.** By J. H. Woodger, D.Sc., Reader in Biology in the University of London. With Appendices by Alfred Tarski and W. F. Floyd. Cambridge: at the University Press, 1937. (Pp. x + 174.) 12s. 6d. net.
- Snakes of the World.** By Raymond L. Ditmars, Litt.D., Curator of Mammals and Reptiles at the New York Zoological Park. New York and London: Macmillan & Co., Ltd., 1937. (Pp. xii + 207, with 85 plates.) 8s. 6d. net.
- The Locust Outbreak in Africa and Western Asia in 1936.** Survey prepared by B. P. Uvarov, D.Sc., Senior Assistant, and Miss W. Milnthorpe, B.Sc., Technical Assistant, Imperial Institute of Entomology. Economic Advisory Council, Committee on Locust Control. London: H.M. Stationery Office, 1937. (Pp. 55, with 9 maps.) 3s. net.
- The Food of North Sea Herring 1930-1934.** By R. E. Savage, A.R.C.Sc., D.I.C., Fisheries Laboratory, Lowestoft. Ministry of Agriculture and Fisheries, Fishery Investigations, Series II, Vol. XV, No. 5, 1937. London: H.M. Stationery Office, 1937. (Pp. 60, with 16 figures and 29 tables.) 3s. net.
- Sea-Trout of the River Conon.** By G. Herbert Nall, M.A., F.R.M.S. Fishery Board for Scotland, Salmon Fisheries, 1937, No. IV. Edinburgh: H.M. Stationery Office, 1938. (Pp. 31, with 8 plates.) 2s. 6d. net.
- Conseil Permanent International pour l'Exploration de la Mer. Rapports et Procès-Verbaux des Réunions, Vol. CI, Part 4.** Copenhagen: Andr. Fred. Høst & Fils, 1938. (Pp. 31, with 3 figures.) Kr. 1.50.
- Conseil Permanent International pour l'Exploration de la Mer. Rapports et Procès-Verbaux des Réunions. Vol. CV. Part I: Procès-Verbaux (Juillet 1937); Part II: Rapport Administratif (1936-1937); Part III: Appendices (1936-1937).** Copenhagen: Andr. Fred. Høst & Fils, 1937. (Part I: pp. 57; Part II: pp. 80, with figures and tables; Part III: pp. 74, with figures and tables.) Kr. 3.00 each.
- Practical Zoological Illustrations. Part I: Vertebrates.** By S. Lockyer and D. R. Crofts. London: Macmillan & Co., Ltd., 1937. 28 cards in portfolio, 10s. 6d. net. Cellophane envelope to take one card, 1s. net.
- The Biological Standardisation of the Vitamins.** By Katharine H. Coward, D.Sc., Reader in Biochemistry, University of London. London: Baillière, Tindall & Cox, 1938. (Pp. viii + 227, with 44 figures and 29 tables.) 12s. 6d. net.
- Toxicity of Industrial Organic Solvents. Summaries of Published Work.** Compiled by Ethel Browning under the direction of the Committee on the Toxicity of Industrial Solvents. Medical Research Council, Industrial Health Research Board, Report No. 80. London: H.M. Stationery Office, 1937. (Pp. iv + 396.) 7s. 6d. net.

- Chemistry of the Brain.** By Irvine H. Page, A.B.(Chem.), M.D., Hospital of the Rockefeller Institute for Medical Research, New York. Baltimore: Charles C. Thomas; London: Baillière, Tindall & Cox, 1937. (Pp. xviii + 444, with 2 figures and 52 tables.) 34s. net.
- Applied Mycology and Bacteriology.** By L. D. Galloway, M.A., Imperial Mycologist, New Delhi, 1934-1937, and R. Burgess, M.Sc., Ph.D., Dairy Bacteriologist to Lancs. County Council. London: Leonard Hill, Ltd., 1937. (Pp. x + 186, with 4 figures.) 10s. net.
- An Introduction to Bacteriological Chemistry.** By C. G. Anderson, Ph.D., D.Bact., Lewis Cameron Teaching Fellow, Bacteriology Department, University of Edinburgh. Edinburgh: E. & S. Livingstone, 1938. (Pp. viii + 278, with 5 figures and 19 tables.) 10s. 6d. net.
- An Introduction to Physical Anthropology.** By E. P. Stibbe, F.R.C.S., Reader in Anatomy in the University of London, King's College. Second edition. With an Appendix by W. A. M. Smart, M.B., B.Sc., B.Sc. London: Edward Arnold & Co., 1938. (Pp. viii + 230, with 56 figures.) 10s. 6d. net.
- Civilisation and Disease.** By C. P. Donnison, M.D., M.R.C.P. With an Introduction by Sir Walter Langdon-Brown, M.A., M.D., Hon. D.Sc., F.R.C.P. London: Baillière, Tindall & Cox, 1937. (Pp. xvi + 222.) 10s. 6d. net.
- Newton's Principia in 1687 and 1937.** By T. M. Cherry, B.A., Ph.D., Professor of Mathematics in the University of Melbourne. Melbourne University Press in association with Oxford University Press, 1937. (Pp. 28.) 1s. net.
- Aristotle. Parts of Animals.** With an English Translation by A. L. Peck, M.A., Ph.D., Fellow of Christ's College, Cambridge, and University Lecturer in Classics, and a Foreword by F. H. A. Marshall, C.B.E., Sc.D., F.R.S. **Movement of Animals—Progression of Animals.** With an English Translation by E. S. Forster, M.A., Professor of Greek in the University of Sheffield. The Loeb Classical Library. London: William Heinemann, Ltd.; Cambridge, Mass.: Harvard University Press, 1937. (Pp. 556.) Cloth, 10s. net; leather, 12s. 6d. net.
- Madame Curie.** By Eve Curie. Translated by Vincent Sheean. London: William Heinemann, Ltd., 1938. (Pp. xiv + 411, with 31 plates.) 18s. net.
- Aristocracy and the Middle-Classes in Germany. Social Types in German Literature 1830-1900.** By Ernst Kohn-Bramstedt, Ph.D. (London), Dr.Phil. (Berlin). With a Foreword by G. P. Gooch, D.Litt., F.B.A. London: P. S. King & Son, Ltd., 1937. (Pp. xii + 362.) 15s. net.
- Animals for Show and Pleasure in Ancient Rome.** By George Jennison, M.A., F.Z.S., late of the Zoological Gardens, Belle Vue, Manchester. Manchester University Press, 1937. (Pp. xiv + 209, with 11 figures and 8 plates.) 12s. 6d. net.
- Le Primat du Phénomène dans la Connaissance. La Philosophie de la Nature, Vol. II.** By Georges Matisse, D.-ès-Sc. Bibliothèque de Philosophie Contemporaine. Paris: Librairie Félix Alcan, 1938. (Pp. 280, with 34 figures.) Fr. 40.-.

- Psychology Down the Ages.** By C. Spearman, Ph.D., Hon.L.L.D., F.R.S., Emeritus Professor of Psychology in the University of London. Vols. I and II. London: Macmillan & Co., Ltd., 1937. (Vol. I: pp. xii + 454, with 27 figures and tables; Vol. II: pp. viii + 355, with 26 figures and tables.) 30s. net.
- The Nature and Meaning of Evil and Suffering as seen from the Evolutionary Standpoint.** By C. J. Bond, C.M.G., F.R.C.S., F.L.S. London: H. K. Lewis & Co., Ltd., 1937. (Pp. 29.) 1s. net.
- What Science Really Means. An Explanation of the History and Empirical Method of General Science.** By Julius W. Friend and James Feibleman. London: George Allen & Unwin, Ltd., 1937. (Pp. 222.) 7s. 6d. net.
- The World and Man as Science Sees Them.** Edited by Forest Ray Moulton, A.B., Ph.D., Sc.D. U.S.A.: University of Chicago Press; Great Britain and Ireland: Cambridge University Press, 1937. (Pp. xx + 533, with 178 figures, including 46 tables.) 13s. 6d. net.
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- An Introduction to the Study of Spinning.** By W. E. Morton, M.Sc.Tech., F.T.I., Professor of Textile Technology in the University of Manchester, and Head of the Textile Department, Manchester College of Technology. London, New York, Toronto: Longmans, Green & Co., 1937. (Pp. viii + 267, with 162 figures.) 12s. 6d. net.
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